Chapter 3 Hazard Identification and Risk Assessment

Disaster Mitigation Act of 2000

§201.4(c)(2): Risk assessments that provide the factual basis for activities proposed in the strategy portion of the mitigation plan. Statewide risk assessments must characterize and analyze natural hazards and risks to provide a statewide overview. This overview will allow the State to compare potential losses throughout the State and to determine their priorities for implementing mitigation measures under the strategy, and to prioritize jurisdictions for receiving technical and financial support in developing more detailed local risk and vulnerability assessments.
The risk assessment shall include the following:
§201.4(c)(2)(i): An overview of the type and location of all natural hazards that can affect the State, including information on previous occurrences of hazard events, as well as the probability of future hazard events, using maps where appropriate;
§201.4(c)(2)(ii): An overview and analysis of the State's vulnerability to the hazards described in this paragraph (c)(2), based on estimates provided in local risk assessments as well as the State risk assessment. The State shall describe vulnerability in terms of the jurisdictions most threatened by the identified hazards, and most vulnerable to damage and loss associated with hazard events. State owned critical or operated facilities located in the identified hazard areas shall also be addressed;
§201.4(c)(2)(iii): An overview and analysis of potential losses to the identified vulnerable structures, based on estimates provided in local risk assessments as well as the State risk assessment. The State shall estimate the potential dollar losses to State owned or operated buildings, infrastructure, and critical facilities located in the identified hazard areas.

3.1 *Overview of the Hazard Identification and Risk Assessment (HIRA) Process*

The Hazard Identification and Risk Assessment (HIRA) for the Commonwealth of Virginia Hazard Mitigation Plan was conducted primarily by the Virginia Tech Center for Geospatial Information Technology. The following sections of this chapter will cover the following three main requirements for the HIRA:

Identifying and Profiling Hazards
Assessing Vulnerabilities
Estimating Potential Losses

Two important considerations that run throughout this chapter are overall data availability and lack of completed local plans. The FEMA guidelines emphasize using "available data" for this plan. Many existing plans and reports exist addressing hazard mitigation for Virginia, such as the eight volume *Commonwealth Emergency Operations Plan* (EOP) (most volumes available at http://www.vdem.state.va.us/library/eplan.cfm). Initially, the Commonwealth considered "converting" the data and information contained within these types of reports into a comprehensive Mitigation Database for purposes of conducting the HIRA. With the onset of Hurricane Isabel and the necessity of bringing in Virginia Tech to assist with completion of the HIRA, the decision was made to develop a minimal Mitigation Database using readily available information in digital formats, preferably already in a Geographic Information System (GIS) format. When appropriate for the analysis for population and state facilities, publicly available maps and data tables were converted to work within a GIS context. However, for other at-risk assets, such as transportation infrastructure, where data security and availability issues arose, the existing plans and reports were deemed adequate in their current format to address the Federal requirements for this current version of the Virginia Hazard Mitigation Plan.

The data availability issues were also compounded by the lack of any completed local plans during the time period when the Virginia HIRA was being conducted (Dec. 2003 – Feb. 2004). This absence of local information about features such as local critical facilities and infrastructure greatly limited the scope of the Commonwealth HIRA. In the following sections of this chapter, the impact of these data limitations will be shown through the different vulnerability assessment and loss estimation methods used for hazards.

3.2 *Identifying and Profiling Hazards*

Based on the Federal Guidelines, the HIRA only focused on natural hazards and their impact on the Commonwealth. It should be noted that almost all volumes of the *Virginia EOP* either directly or indirectly address human-caused hazards to varying extents.

Federal Disasters

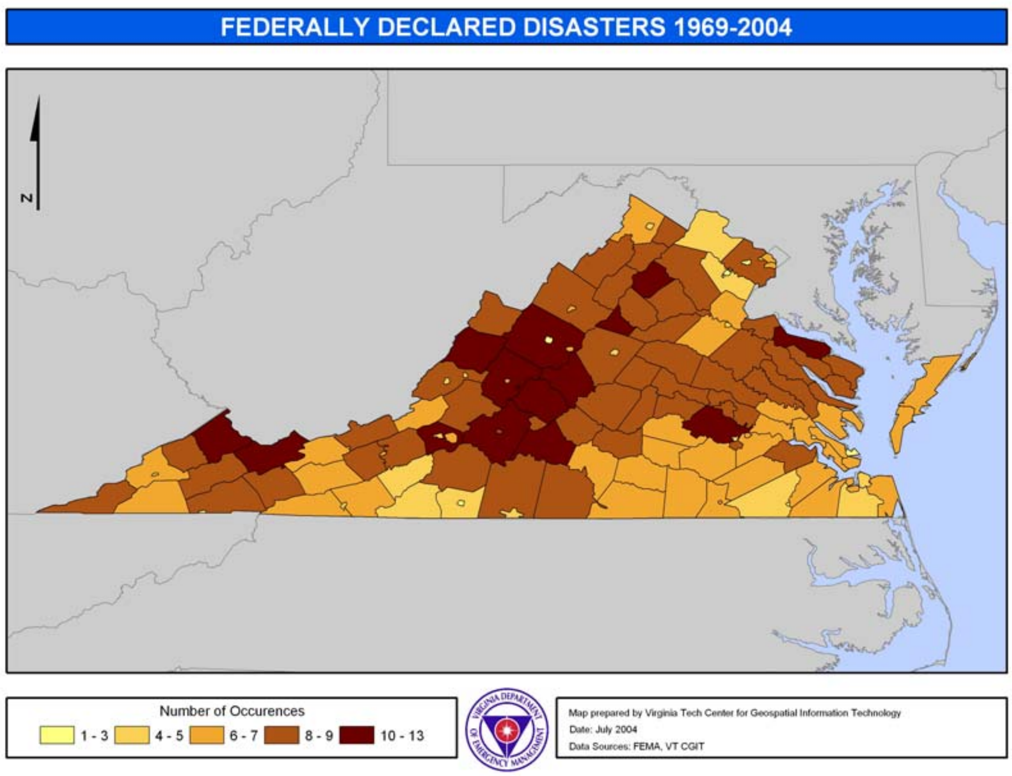


Figure 3-1. Federally Declared Disasters in Virginia from 1969 through June 2004.
Note: All maps in this chapter are included in Appendix F in full page landscape format.

Figure 3-1 shows the extent of federally declared disasters in Virginia. The map shows that 15 counties and cities have had 10 or more disasters in the last 35 years.

Table 3-1 lists these disasters, the type of disaster, and the number of jurisdictions declared.

Table 3-1. Presidential Disaster Declarations in Virginia Since 1969

Date	Type	Jurisdictions Declared
August 1969	Hurricane Camille	27
June 1972	Hurricane Agnes	106
September 1972	Storm/Flood	3
October 1972	Flood	31
April 1977	Flash Flood	16
November 1977	Flood	8
July 1979	Flood	1
September 1979	Flood	1
May 1984	Flood	3
November 1985	Flood	52
October 1989	Flood	1
April 1992	Flood	24
March 1993	Snowstorm	43
August 1993	Tornado	1
February 1994	Ice Storm	71
March 1994	Ice Storm	29
June 1995	Flood	24
January 1996	Blizzard	All counties & cities
January 1996	Flood	27
September 1996	Hurricane Fran	88
August 1998	Hurricane Bonnie	5
September 1999	Hurricane Dennis	1
September 1999	Hurricane Floyd	48
February 2000	Winter Storm	107
July 2001	Flood	10
September 2001	Pentagon Attack	1
March 2002	Flood	10
April/May 2002	Flood	9
February 2003	Winter Storms/Flood	39
September 2003	Hurricane Isabel	100
November 2003	Flood	6
May 2004	Flood	3

Reference:
Virginia Department of Emergency Management (VDEM). 2004. Presidential Disaster Declarations in Virginia Since 1969. < http://www.vdem.state.va.us/library/dishist.cfm > (8/19/2004).

Listed below is more information about these and other major disasters in Virginia's recent history:

- **Ash Wednesday Storm in 1962.** Damage was experienced up and down Virginia's Tidewater region. Houses along the coast and bay region were damaged and flooded by high waves and 7 to 9 foot water rises, Virginia Beach's concrete boardwalk and sea wall were damaged, and extensive shoreline erosion occurred. The city of Hampton alone had an estimated $4 million in wind and flood damage.
- **Hurricane Camille in 1969**. This major storm made landfall out of the gulf as a category 5 and weakened to a tropical depression before reaching the state. Precipitation trained over regions many hours, dropping more than 27 inches of rain in Nelson County and over ten inches in the area from Lynchburg to Charlottesville. Flooding and landslides, triggered by saturated soils, resulted in catastrophic damage. More than 150 people died and another 100 were injured. At the time, damage was estimated at more than $113 million.
- **Tropical Storm Agnes in 1972.** This event produced devastating flooding throughout the Mid-Atlantic States. Some areas of eastern Virginia received over 15 inches of rainfall as the storm moved through. The Potomac and James Rivers experienced

major flooding, which created 5 to 8 feet flood waters in many locations along the rivers. Richmond was impacted the most by these high water levels. Water supply and sewage treatment plants were inundated, as were electric and gas plants. Only one of the five bridges across the James River was open, while the Downtown area was closed for several days and businesses and industries in the area suffered immense damage. Sixteen people lost their lives in the state and damage was estimated at $222 million. These startling numbers resulted in 63 counties and 23 cities qualifying for disaster relief.

- **Tornado in 1973.** This F3 tornado is worth noting because it touched down in heavily populated areas of Northern Virginia and caused $25 million in total damages. The tornado touched down in Price William County and traveled through the cities of Fairfax and Falls Church before dissipating. Fairfax was hit hardest by this tornado; within one 6 mile stretch of damage path, a high school, two shopping centers, an apartment complex, and 226 homes were damaged.
- **Super Tornado Outbreak in 1974.** This was the worst tornado outbreak in U.S. history, generating the most tornadoes in a 24 hour period. Several states were struck with 148 observed tornadoes, killing 315 people and inuring thousands more. Eight of these tornadoes occurred in Virginia. Wind damage was reported in counties from Russell northward to Loudoun. Hundreds of homes and barns and many mobile homes were damaged or destroyed.
- **The Blizzard of 1983.** An unusually large area of the state was covered with more than 12 inches of snow, setting new records in many places. Richmond received 18 inches, while portions of northern Virginia had almost 30 inches. Strong winds that gusted over 25 mph created high snow drifts and made clearing of roads a tough task. This storm cost the state more than $9 million in snow clearance alone.
- **Severe Weather Outbreak, 1984.** Severe weather pushed through the state on May 8th of this year, spawning tornadoes and producing significant downburst wind damage in central and eastern Virginia. There was extensive home, mobile home, building, and tree damage from these cluster thunderstorms' imbedded tornadoes and wind storms, and total damage costs were around $50 million.
- **Election Day Flood, 1985.** Heavy rainfall from October 31 through November 6, 1985, caused record-breaking floods over a large region, including western and northern Virginia. Most of the rain fell on November 4 and 5 causing flash flooding. Heavy rainfall was indirectly related to Hurricane Juan. The Roanoke River rose seven feet in one hour and 18 feet in six hours, cresting at 23 feet on November 5 .There was 22 deaths in Virginia as a result of the flooding. FEMA declared 50 jurisdictions disaster areas, 1.7 million people were affected by the flooding. Flooding damages were estimated at $800 million.
- **The Storm of the Century, 1993.** Affecting nearly the entire East Coast, this storm killed 200 people and generated a few billion dollars of damage and snow removal costs. Although its effects in Virginia did not exceed the Ash Wednesday Storm in 1962, it affected more communities ranging from the Chesapeake Bay through the center part of the state and reaching into Southwest Virginia. Blizzard conditions in western Virginia dropped 2 to 3 feet of snow and produced snowdrifts up to 12 feet deep. Snow removal and clean-up costs were estimated at $16 million for the state.
- **The Petersburg/Colonial Heights Tornado in 1993.** This tornado outbreak killed four people and injured another 238 people; The strongest tornado touched down in Petersburg as an F4, with maximum winds estimated at 210 mph. Major damage occurred in the Old Towne section of Petersburg, and destroyed several stores and businesses in Colonial Heights. Other tornadoes hit the same day in the City of Newport News and the City of Chesapeake. In only 4 hours, 18 tornadoes were able to carve paths through southeast Virginia, setting a new record for the Commonwealth.

Total damages were estimated to be $52.5 million, making it Virginia's most costly tornado outbreak to date.

- **Ice Storm of 1994.** This winter storm coated portions of Virginia with 1 to 3 inches of ice from freezing rain and sleet. This led to the loss of approximately 10 to 20 percent trees in some counties, which blocked roads and caused many people to be without power for a week. There were numerous automobile accidents and injuries from people falling on ice. Damages were estimates at $61 million.
- **The Blizzard and flooding of Winter 1996.** Also known as the "Great Furlough Storm" due to Congressional impasse over the federal budget, the blizzard paralyzed the Interstate 95 corridor, and reached westward into the Appalachians where snow depths of over 48 inches were recorded. Several local governments and schools were closed for more than a week. The blizzard was followed with another storm, which blanketed the entire state with at least one foot of snow. To compound things, heavy snowfall piled on top of this storm's accumulations in the next week, which kept snow pack on the ground for an extended period of time. This snow was eventually thawed by higher temperatures and heavy rain that fell after this thaw resulted in severe flooding. Total damage between the blizzard and subsequent flooding was over $30 million.
- **Hurricane Fran in 1996.** This hurricane is notable not only for the $350 million in damages, but because of its widespread effects, including a record number of people without power and the closure of 78 primary and 853 secondary roads. Rainfall amounts between 8 and 20 inches fell over the mountains and Shenandoah Valley, leading to record-level flooding in many locations within this region. 100 people had to be rescued from the flood waters and hundreds of homes and buildings were damaged by the flood waters and high winds.
- **The Christmas Ice Storm, 1998.** This prolonged ice storm struck central and southeast Virginia in the days leading up to Christmas. Ice accumulations exceeded an inch, bringing down many trees and power lines within this region. 400,000 people were without power on Christmas Eve, and some of these people did not get their power back for up to ten days. Property damage from this storm was estimated to be around $20 million.
- **Wildfires of 1999.** The Purgatory Mountain Fire in Botetourt County, one of the largest fires of the year, burned 1,285 acres and cost over $166,000 to contain. A fire on Clinch Mountain in Southwest Virginia burned only 240 acres but containment costs exceeded $97,000 due to the mountainous terrain and extreme drought conditions. A total of 1,749 fires burned 12,118 acres, considerably exceeding the five-year average of 1,320 fires and 6,081 acres.
- **Hurricane Floyd in 1999.** This large hurricane brought 10 to 20 inches of total rainfall over portions of southeast Virginia, with wind gusts up to 100 mph and storm surges approaching 7 feet along the coast. These three elements combine together to cause total storm damages of approximately $255 million. This disaster will long be remembered in the City of Franklin and Southampton and Isle of Wight Counties, as well as the other 44 Virginia jurisdictions included in the major disaster declaration. More than 8,900 homes, businesses and public facilities were either destroyed, significantly damaged, or sustained moderate impacts. In addition to direct property damage, lost business revenues were estimated at $13.1 million, with the City of Franklin losing nearly $2 million in tax revenues. Direct crop losses were estimated at $17 million. FEMA reports allocating $8.9 million for assistance to families and individuals, and $19.8 million for public assistance.
- **Terrorist Attack, 2001.** American Airlines Flight 77 was hijacked and flown into the Pentagon in Arlington County, Virginia. The hijacking resulted in over 150 fatalities when it crashed into the west side of the building.

- **Southwest Virginia Flooding in 2001-2004.** A total of six federal disasters, primarily flooding and severe storms, have been declared in Southwest Virginia from 2001-2004 (Disasters 1386, 1406, 1411, 1458, 1502, and 1525). The worse hit counties were Tazewell (all 6 disasters), Buchanan (5 disasters), and Russell (4 disasters). Dickenson, Lee, Smyth, and Wise Counties were also declared in half of these six disasters. Many of these disasters have storm tracks along the mountain valleys, producing excessive localized flooding. Catastrophic flooding has been experienced in rural settlements as well as in Bluefield, Hurley, Appalachia, Pennington Gap, Norton, Dante and Wise.
- **Hurricane Isabel in 2003.** Hurricane Isabel entered Virginia September 18 after making landfall along the North Carolina Outer Banks. The Commonwealth sustained tropical storm winds for 29 hours with some maximum winds approaching 100 mph. The hurricane produced storm surge of 5 to 8 feet along the coast and in the Chesapeake Bay with rainfall totals between 2 to 11 inches along its track. Twenty-one inches of rainfall was measured near Waynesboro Virginia. Damages due to wind, rain, and storm surge resulted in flooding, electrical outages, debris, transportation interruption, and damaged homes and businesses. At the height of the incident approximately 6,000 residents were housed in 134 shelters and curfews were imposed in many jurisdictions. Further damages occurred when a series of thunderstorms and tornados came through many of the designated areas in the southeast portion of Virginia on September 23. There were a total of 36 confirmed deaths. More than 93,000 registrations were made for assistance. Residential destruction included 1,186 homes reported destroyed and 9,110 with major damage, 107,908 minor damage, with losses estimated over $590 million. Of the 1,470 businesses involved, 77 are reported destroyed, 333 suffered major damage and 1,060 businesses suffered minor or casual damage, with losses exceeding $84 million. Public assistance exceeds $250 million and continues to increase. More than two-thirds of the households and businesses within the Commonwealth were without power. Remote locations did not have power restored for three weeks.

This brief overview of major recent disasters shows how flood, wind, fire, and winter storms have a devastating impact on Virginia. The following sections will expand from this historical overview of hazards to specifics about prediction of their future occurrence.

Natural Hazard Overview

Table 3-2 provides an overview of all natural hazards included with this Plan. The relative risk category relates to a subjective ranking procedure, which will be described in Section 3.3. The Analysis Level shows how all of hazards were addressed in the Plan. An emphasis was made in the HIRA to conduct analysis for all high relative risk hazards, and for medium and low hazard when data was available.

Table 3-2. Natural Hazards Addressed in the Virginia Hazard Mitigation Plan

Hazard	Type	Relative Risk Category	Analysis Level	Data Reference
Blizzards/ Winter Storms	Including winter storms, Nor'easters, ice storms, and excessive cold	High	Covered by HIRA Winter Storm Analysis	NOAA National Weather Service Records (Ref. 4,6)
Coastal/ Shoreline Erosion		Medium	Described under Flooding	
Dam Failure		Low	Description Only	Virginia EOP Volumes 1 and 8
Drought	Including excessive heat	Medium	Description Only	Drought Monitor (Ref. 11)
Earthquake		Low	Description Only	USGS (Ref. 9)
Flooding	Coastal	Medium	Covered by HIRA Flood Analysis	FEMA DFIRM, Q3, and FIRM Mapping (Ref. 2)
	Riverine	High		
High Wind/ Windstorm	Including Thunderstorms and Lighning	Low	Covered by HIRA Wind Analysis	ASCE Design Wind Speed Maps (Ref. 1, 2)
Hurricane	Hurricane, generally	Medium	Covered by HIRA Flood and Wind Analyses	FEMA DFIRM, Q3, and FIRM Mapping and ASCE Design Wind Speed Maps (Ref. 1, 2)
	Tropical Depressions	Low		
	Tropical Storms	Medium		
	Category 1	Medium		
	Category 2	High		
	Category 3	Low		
Land Subsidence	Karst only	Low	Covered by HIRA Karst Analysis	USGS (Ref. 8)
Landslide		Low	Covered by HIRA Landslide Analysis	USGS (Ref. 7)
Tornado	Tornados, generally and hail	High	Covered by HIRA Tornado Analysis	NOAA National Weather Service Records (Ref. 3)
	F0	Medium		
	F1	High		
	F2	Low		
Wildfire		High	Covered by HIRA Wildfire Analysis	Virginia Department of Forestry (Ref. 10)

References:
1. American Society of Civil Engineers (ASCE), *Minimum Design Loads for Buildings and Other Structures*, ASCE 7- 98. 1998. Public Ballot Copy, American Society of Civil Engineers. Reston, VA.
2. Federal Emergency Management Agency (FEMA). 2003a. "The FEMA Map Store", *Federal Emergency Management Agency, Department of Homeland Security*, <http://store.msc.fema.gov/> (6/24/2004).
3. National Oceanic and Atmospheric Administration (NOAA) Storm Prediction Center. 1999. "Historical Tornado Data Archive", *National Oceanic and Atmospheric Administration Storm Prediction Center,* <http://www.spc.noaa.gov/archive/tornadoes/>, (6/24/2004).
4. National Oceanic and Atmospheric Administration (NOAA) National Climatic Snow Center. 2002. "United States Snow Climatology", *National Oceanic and Atmospheric Administration National Climatic Snow Center,* <http://lwf.ncdc.noaa.gov/oa/climate/monitoring/snowclim/mainpage.html>, (6/24/2004).
5. National Oceanic and Atmospheric Administration (NOAA) National Weather Service Tropical Prediction Center: National Hurricane Center. 2004. "NHC/TPC Archive of Past Hurricane Seasons.", *National Weather Service Tropical Prediction Center: National Hurricane Center,* <http://www.nhc.noaa.gov/>, (6/24/2004).
6. Southeast Regional Climate Center (SERCC). 2004. "Historical Climate Summaries for Virginia", *Southeast Regional Climate Center,* <http://www.dnr.state.sc.us/climate/sercc/climateinfo/historical/historical_va.html>, (6/24/2004).
7. United States Geological Survey (USGS). 2002a. "Landslide Incidence and Susceptibility of the Conterminous United States", *United States Geological Survey, Department of the Interior,* <http://nationalatlas.gov/lsoverm.html> (6/24/2004).
8. United States Geological Survey (USGS). 2002b. "Principal Aquifers of the 48 Conterminous United States, Hawaii, Puerto Rico, and the U.S. Virgin Islands", *United States Geological Survey, Department of the Interior,* << http://nationalatlas.gov/atlasftp.html> (6/24/2004).
9. United States Geological Survey (USGS). 2003. "Earthquake Hazards Program", *United States Geological Survey, Department of the Interior,* <http://earthquake.usgs.gov/> (6/24/2004).
10. Virginia Department of Forestry (VDOF). 2004. "Wildfire Risk Analysis", *Virginia Department of Forestry,* <http://www.vdof.org/gis/> (6/24/2004).
11. Drought Monitor. 2004. *Drought Monitor,* << http://drought.unl.edu/dm/archive/99/classify.htm> (6/24/2004).

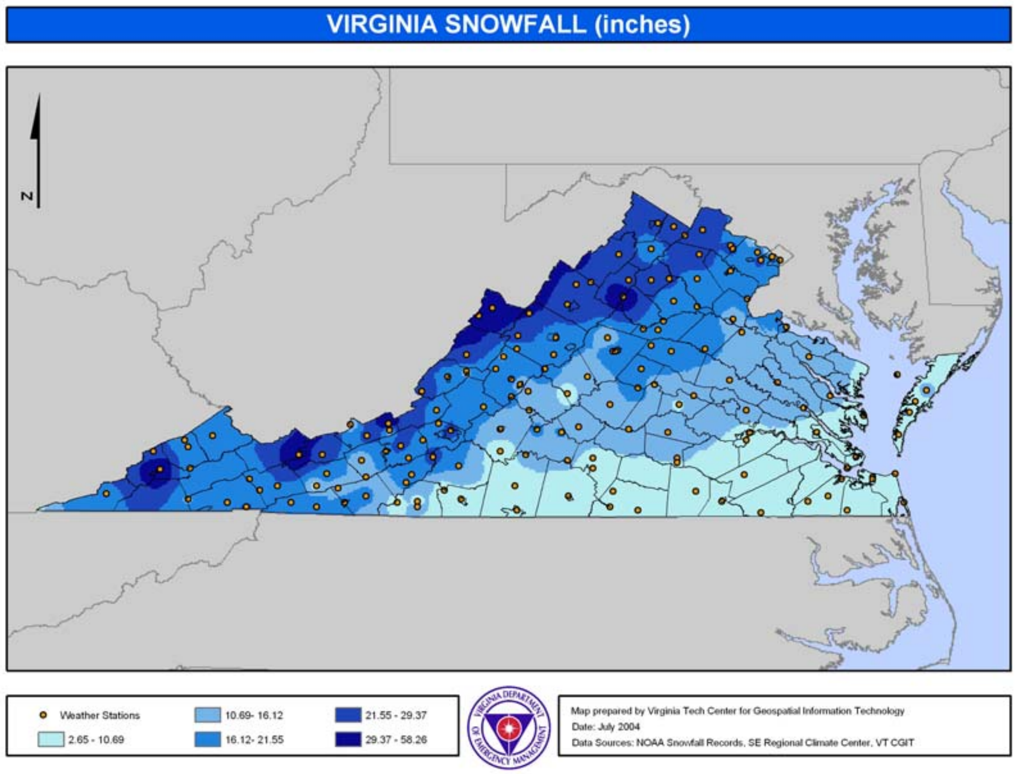
Blizzards Including winter storms, ice storms, excessive cold

Historic Occurrence

The following list, based on available records from VDEM and the NWS, denotes the major winter storms and blizzards in Virginia since 1900:

- Winter Storm, 1908
- Winter Storm, 1912
- Winter Storm, 1921
- “Knickerbocker Storm”, 1922
- Winter Storm, 1927
- Winter Storm, 1936
- Winter Storm, 1938
- Winter Storm, 1940
- “Palm Sunday Snowstorm”, 1942
- Winter Storm, 1943
- Winter Storm, 1956
- Winter Storm, 1958
- The Winter of 1960-1961
- Ash Wednesday Storm, 1962
- Winter Storm, 1966
- Winter Storm, 1977
- Winter Storm, 1978
- Winter Storm, 1979
- “The Presidents Day Storm”, 1979
- Winter of 1980
- “Blizzard of ‘83”
- Winter Storm, 1984
- Winter Storm, 1985
- Winter Storm, 1989
- “Superstorm of March’93” or “The Storm of the Century” $15.5 million in property damages.
- Ice Storm, 1994
- “Blizzard of ‘96” or “Great Furlough Storm” Estimated property damages greater than $1.3 million.
- Winter of 1995 - 1996
- “Back to Back Nor’easters”, 1998
- “Alberta Clipper” 1999

Figure 3-2 shows annual snowfall distribution in inches throughout Virginia, based on records from over 100 NWS stations.



<u>Description</u>

The winter months can bring a wide variety of natural hazards to the Commonwealth, including blizzards, snowstorms, ice, sleet, freezing rain, and extremely cold temperatures. All of these weather events can be experienced throughout the state, depending on the depth of cold air that is in place over the region when the storm event comes. Virginia's biggest winter weather threats come from Northeasters or Nor'easters. These large storms form along the southern Atlantic coast and move northeast into Virginia along the Mid-Altlantic coast. These events can bring strong winds and anything from rain to ice to snow to even blizzard conditions over a very large area. This combination of heavy frozen precipitation and winds can be quite destructive and lead to widespread utility failures and high cleanup costs. Nor'easters may occur from November through April, but are usually at their worst in January, February, and March.

The State Climatologist's Office reports the following winter extremes:

- Lowest temperature of -30°F, recorded on January 21, 1985 at the Mountain Lake Biological Station.
- Greatest 24-hour snowfall of 33 inches, recorded on March 6, 1962 at Big Meadows.
- Highest single storm snowfall of 48 inches, recorded January 6-7, 1996 at Big Meadows.
- Greatest seasonal snowfall of 124.2 inches during the 1995-1996 winter season, recorded in Wise County.

- Major winter storms typically affect large areas of the nation. In the 1990s, winter storms in Virginia resulted in more localities qualifying for major disaster declarations than any other hazard.

Excessively cold temperatures are not an annual event in the Commonwealth. Although wind chill advisories are issued nearly every year, especially in Western and Northern Virginia, life-threatening excessive cold, requiring wind chill warnings, is a rare occurrence in Virginia. The frequency of occurrence is dependent entirely upon the excessive cold criteria used (i.e. wind chill vs. air temperature).

Impacts and Measures of Magnitude

The impacts of winter storms are minimal in terms of property damage and long term effects. The most notable impact from winter storms is the damage to power distribution networks and utilities. Severe winter storms have the potential to inhibit normal functions of the state. Governmental costs for this type of event are a result of the needed personnel and equipment for clearing streets. Private sector losses are attributed to lost work when employees are unable to travel. Homes and businesses suffer damage when electric service is interrupted for long periods of time. Health threats can become severe when frozen precipitation makes roadways and walkways very slippery and due to prolonged power outages and if fuel supplies are jeopardized. Occasionally, buildings may be damaged when snow loads exceed the design capacity of their roofs or when trees fall due to excessive ice accumulation on branches. The primary impact of excessive cold is increased potential for frostbite, and potentially death as a result of over-exposure to extreme cold. Some secondary hazards extreme/excessive cold present is a danger to livestock and pets, and frozen water pipes in homes and businesses.

Additional Information

The VDEM online library at **www.vdem.state.va.us/library/stats.cfm** includes an extensive background on the history and impacts of snow, Nor'easters, wind, ice and cold in the Commonwealth by the National Weather Service.

Proposed projects (Information and Data Development: Identify data needs) for blizzards/winter storms and natural hazards information would provide data for future analysis in upcoming plans. Projects include: 3.1.1 Climate and Natural Hazard Information Collection; 3.1.2 Establish and Maintain the Virginia Mitigation Database. Additional information regarding the projects can be found in Appendix H.

Dam Failure

Historic Occurrence

There are no established databases in Virginia of historical dam failures. Most dam failures occur due to lack of maintenance of dam facilities in combination with excess precipitation events, such as hurricanes and thunderstorms. Recent dam failures have included the Powhatan Lakes Dam, which failed due to a heavy storm during the summer of 2004, and the Swift Creek Dam, which was overtopped during Tropical Storm Gaston flooding in late summer 2004.

Description

Dam failure poses a risk when there are large potential areas with large populations surrounding dams. On-going dam inspections and Virginia's participation in the National Dam Safety Program maintained by FEMA and the U.S. Army Corps of Engineers serve as preventative measures against dam failures. Dams may also be targeted by terrorists and therefore represent a potential hazard.

The Virginia Department of Conservation and Recreation, Division of Dam Safety's mission is to conserve, protect, enhance, and advocate he wise use of the Commonwealth's unique natural, historical, recreational, scenic and cultural resources. The program's purpose is to provide for safe design, construction, operation and maintenance of dams to protect public safety. Disaster recovery programs include assistance to dam owners and local officials in assessing the condition of dams following a flood disaster and assuring the repairs and reconstruction of damaged structures are compliant with the National Flood Insurance Program (NFIP) regulations.

Impacts

Failure of dams may result in a localized major impact. Impacts include loss of human life, economic loss, lifeline disruption and environmental impact such as destruction of habitat.

Measures of Magnitude

In 2001 the dam inventory mapping and classification system was changed. The classes now range in descending order from Class I to Class IV with Class I having the greatest potential for adverse downstream impacts in event of failure. This classification is not related to the physical condition of the dam nor the probability of its failure. As a result of the updated classification system no data is available for the number of dams in each of the listed classes. DCR Division of Dam Safety is currently working on this.

Dams are classified with a hazard potential depending on the downstream losses estimated in event of failure. Hazard potential is not related to the structural integrity of a dam but strictly to the potential for adverse downstream effects if the dam were to fail. Frequency of dam inspection is dependent of how the dam is classified (see table below). The owner of each regulated Class I, II, and III dam is required to apply to the Soil and Water Conservation Board for an operation and maintenance certificate. Table 3-3 shows more information on these classes

Table 3-3 Dam Classification System in Virginia.

Class	**Description**	**Inspection**
Class I	Dams which upon failure would cause probable loss of life or excessive economic loss	Inspected every two years.
Class II	Dams which upon failure could cause possible loss of life or appreciable economic loss	Inspected every three years.
Class III	Dams which upon failure would not likely lead to loss of life or significant economic loss	Inspected every six years, upon renewal of the certificate.
Class IV	Dams which upon failure would not likely lead to loss of life or economic loss to others	Inspection not applicable for Class IV.

Secondary impacts from dam failure include flooding to the surrounding areas. Dam hazard classification indicates the possible effects on downstream areas if dam failure were to occur.

Additional Information

The Virginia Emergency Operation Plan for the Basic Plan and Terrorism (vol.1 & 8) provides information on this hazard. References from Virginia Department of Emergency Management Emergency Operations Plan Volume 6: part III; FEMA 333: National Dam Safety Program. Virginia DCR webpage www.dcr.virginia.gov.

Proposed projects (Information and Data Development: Identify data needs) for dam failure historical data and current information would provide data for future analysis in upcoming plans. Projects include: 3.1.2 Establish and Maintain the Virginia Mitigation Database; 3.1.5 Comprehensive Dam Information Database Development; 3.1.7 Dam Inundation Areas Mapping and Risk Assessment. Additional information regarding the projects can be found in Appendix H.

Drought Including Excessive Heat

Historic Occurrence

The following list, based on available records from VDEM and the NWS, denotes the major recorded droughts in Virginia's history:

- 1824-1826
- 1930-1932 categorized as the "drought of record"
- 1934
- 1962-1971 Less severe drought when compared to 1930. Cumulative stream flow deficit was greatest because of the duration of the drought.
- 1980-1982 Short duration of drought, less severe
- 1985-1988 SE USA Drought
- 1993 Dry and hot weather caused and estimated $75 million in crop damages in 23 counties.
- 1995 Suffolk City. Crop losses estimated at $13.3 million. City was declared a Drought Disaster Area.
- 1997 Northern, Central and Eastern Virginia. Crop damage estimated at $73.8 million.
- 1998 Eastern piedmont and northern neck of Virginia. Crop damage estimated at $66.5 million.
- 1999 Northern Virginia. Crop damages were estimated at $83 million
- 2000-2002

Description

Drought is a phenomenon that, in one form or another, affects the Commonwealth on nearly an annual basis. Drought has several definitions, depending upon the impact. **Agricultural drought** is the most common form of drought, and is characterized by unusually dry conditions during the growing season. **Meteorological drought** is defined as an extended period (generally 6 months or more) when precipitation is less than 75 percent of normal during that period. If coincident with the growing season, agricultural and meteorological drought can occur simultaneously. In general, hydrologic drought is the most serious, and has the most wide reaching consequences. Hydrologic drought occurs due to a protracted period of meteorological drought, which reduces stream flows to extremely low levels, and creates major problems for public (reservoir/river) and private (well) water supplies. This data should be obtained from the Virginia State Climatology office, in conjunction with the Virginia Dept. of Environmental Quality.

Associated with drought is excessive heat, which is a phenomenon that is generally confined to the months of July and August, although brief periods of excessive heat have occurred in June and September. The primary impact of excessive heat is increased potential for hypothermia, which can be fatal to the elderly and infirmed. In addition, there is an increased risk of dehydration, if proper steps are not taken to ingest adequate amounts of non-alcoholic fluids. Excessive heat can be defined either by actual air temperature, or by the heat index, which relates the combined effects of humidity and air temperature on the body. Excessive heat is not an annual event in the Commonwealth. Although heat advisories are issued near every year, especially in the urban areas of Northern Virginia, life-threatening excessive heat is a rare occurrence in Virginia. The frequency of occurrence is dependent entirely upon the excessive heat criteria used (i.e. heat index vs. air temperature).

Impacts

Extended periods of drought can impact crop yields and hay yields, and significant crop losses can result. The impact of meteorological drought can vary significantly, depending upon the length of the dry period, the time of year the dry period occurs, the antecedent moisture conditions prior to the onset of the dry period, and the relative dryness (in percent of normal precipitation) of the period in question.

The impact of excessive heat is most prevalent in urban areas, where urban heat island effects prevent inner-city building from releasing heat built up during the daylight hours. Secondary impacts of excessive heat are severe strain on the electrical power system, and potential brownouts or blackouts.

Measures of Magnitude

Table 3-4 provides a summary of drought categories and impacts. Notice that water restrictions start off as voluntary and then become required. For excessive heat, the National Weather Service utilizes heat index thresholds as criteria for the issuance of heat advisories and excessive heat warnings.

Table 3-4 Drought Severity Classification

Category	Description	Possible Impacts
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures; fire risk above average. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered.
D1	Moderate Drought	Some damage to crops, pastures; fire risk high; streams, reservoirs, or wells low, some water shortages developing or imminent, voluntary water use restrictions requested
D2	Severe Drought	Crop or pasture losses likely; fire risk very high; water shortages common; water restrictions imposed
D3	Extreme Drought	Major crop/pasture losses; extreme fire danger; widespread water shortages or restrictions

Additional Information

Concurrent with develop of this Plan, Virginia had a Drought Task Force working on short and long term drought planning in Virginia. Although their report and results were not available for this HIRA, they will be used in future updates to this plan. The Virginia drought website is at http://www.deq.virginia.gov/watersupply/drought.html. More general information about drought is available at the Drought Monitor website at http://drought.unl.edu/dm/archive/99/classify.htm. Information about excessive heat comes from the National Weather Service.

Proposed projects (Information and Data Development: Identify data needs) for droughts and natural hazards information would provide data for future analysis in upcoming plans. Projects include: 3.1.1 Climate and Natural Hazard Information Collection; 3.1.2 Establish and Maintain the Virginia Mitigation Database. Additional information regarding the projects can be found in Appendix H.

Earthquake

Historic Occurrence

The following list, based on available records from VDEM and the Virginia Tech Seismological Observatory, denotes the most significant earthquakes in Virginia's history:

- The first recorded earthquake was in 1774. Since that time there have been more than 300 events. Of the seismic events, 18 were measured 4 - 4.5 or higher on the Richter scale.
- Over 160 earthquakes have been detected in and around Virginia during the years between 1974 and 1993. The Virginia Department of Mines, Minerals and Energy has reported that many earthquakes were reported as being "felt" by local residents.
- 1907. February 11 Near Arvonia, Buckingham County, Va. Felt throughout southwest Virginia and south to Raleigh N.C.
- 1918 April 10(April 9) Luray, Page County, Va. Also felt in Maryland, Pennsylvania and West Virginia
- 1919 September 6 (September 5) Near Front Royal, Warren County, Va. Also felt in parts of Maryland and West Virginia.
- 1929 December 26 (December 25) Charlottesville, Albemarle County, Va. Felt in other parts of the county.
- 1959 April 23 Giles County, Va. Magnitude 3.8 Mfa DG. Also felt in West Virginia.
- 1975 November 11 Southwest Virginia. Also felt in Pulaski County.
- 1976 September 13 Southwest Virginia. Earthquake was observed in North Carolina, Virginia, South Carolina and West Virginia.

Figure 3-3 shows earthquake probability for Virginia.

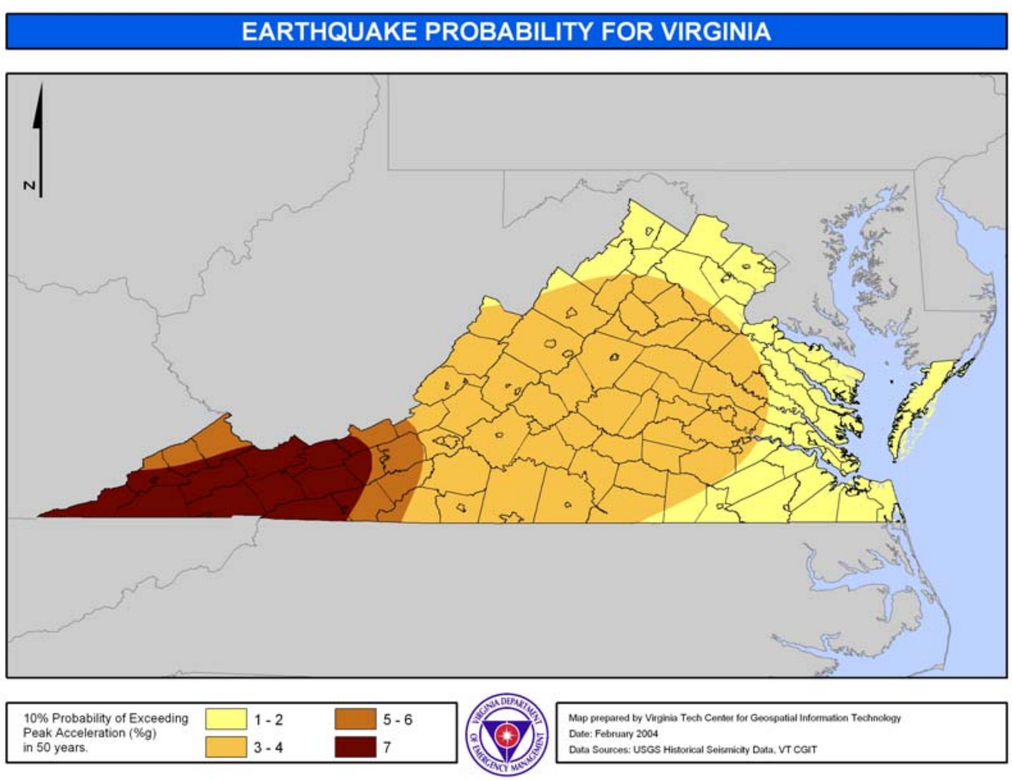


Figure 3-3 Earthquake Peak Acceleration for Virginia (Source: USGS).

Description

Earthquakes are described as a violent, sudden shaking of the earth's surface. This movement results from displacement of rock masses in the upper portion of the earth's surface. Earthquakes usually occur without warning. The risk of an earthquake event in Virginia is moderate.

In 2000, FEMA released a nationwide evaluation, *HAZUS 99 Estimated Annualized Earthquake Losses in the United States* (FEMA 366, 2000). The evaluation considers two measures of losses:

- Annualized Earthquake Losses in any single year; and
- Annualized Earthquake Loss Ratio, which is a measure of seismic risk in relation to the value of the building inventory. The ratio is considered a more accurate picture of seismic risk and makes it easier to compare between regions.

FEMA's evaluation ranked Virginia 34th in the nation. This validates that Virginia's risk of earthquakes is moderate compared to other hazards.

Impacts

Impacts from earthquakes can be severe and cause significant damage. Ground shaking can lead to the collapse of buildings and bridges; disrupt gas, life lines, electric, and phone service. Death, injuries and extensive property damage are possible impacts from this hazard.

Some secondary hazards may include fire, hazardous material release, landslides, flash flooding, avalanches, tsunamis and dam failure.

Measures of Magnitude

The magnitude of an earthquake is measured by the seismic waves that are the vibrations from the earthquake that travel through the earth. The measurements are expressed by the Richter Scale. The United States Geological Survey (USGS) indicates that earthquakes with a magnitude of about 2.0 or less are usually call microearthquakes; they are not commonly felt by people and are generally recorded only on local seismographs. Events with magnitudes of about 4.5 or greater are strong enough to be recorded by sensitive seismographs all over the world. Great earthquakes have magnitudes of 8.0 or higher. On the average, one earthquake of such size occurs somewhere in the world each year. The Richter Scale has no upper limit.

The magnitude of an earthquake as recorded by the Richter Scale does not necessarily imply the magnitude of damage. The extent of damage also depends on the amount of structure present in the area disrupted by the earthquake.

Additional Information

More information about Virginia earthquakes can be found at Virginia Tech Seismological Observatory website at http://www.geol.vt.edu/outreach/vtso/ and at the USGS website at http://earthquake.usgs.gov/.

Proposed projects (Information and Data Development: Identify data needs) for earthquakes and natural hazards information would provide data for future analysis in upcoming plans. Projects include: 3.1.1 Climate and Natural Hazard Information Collection; 3.1.2 Establish and Maintain the Virginia Mitigation Database. Additional information regarding the projects can be found in Appendix H.

Flooding (Riverine & Coastal)

Historic Occurrence

The following list, based on available records from VDEM and the NWS, denotes the most significant floods in Virginia since 1930:

- March 18-19, 1936 "The Great Spring Flood" The Potomac, Shenandoah, Rappahannock, James and York Rivers flooded. The months prior to the flood were marked with low temperatures and heavy snowfalls. Warmer temperatures and rainfall in March resulted in melting snow and rivers to rise.
- April 26-27, 1937 Heavy rains caused widespread flooding. Damages to roads and bridges approached half a million dollars and agricultural losses around a million dollars.
- August 14-18, 1940
- October 15-17, 1942 This flood is considered the worst river flood in Virginia. Damages to the Rappahannock neared $2.5 million and $4.5 million on the Potomac River. Over 1,300 people were left without homes in Albemarle, Spotsylvania, Stafford and Warren Counties. Transportation was disrupted for three days and severe damages and losses occurred to Virginia agriculture.
- August 18-20, 1955 "Diane" Heavy rains resulted in flash flooding along the piedmont and in the Shenandoah Valley.
- Ash Wednesday Storm, 1962 Described earlier in the discussion on federally declared disasters
- August 20-22, 1969 "Camille" Described earlier in the discussion on federally declared disasters
- June 21-24, 1972 "Agnes" Described earlier in the discussion on federally declared disasters
- November 4-7, 1985 "Election Day Flood" Described earlier in the discussion on federally declared disasters
- January 19-22, 1996 "The Great Melt Down" Described earlier in the discussion on federally declared disasters
- September 6-8, 1996 "Fran" Described earlier in the discussion on federally declared disasters
- September 15-16, 1999 "Floyd" Described earlier in the discussion on federally declared disasters
- September 18-19, 2003 "Isabel" " Described earlier in the discussion on federally declared disasters

Figure 3-4 shows the locations of watershed within Virginia. The watersheds in the northern and eastern parts of the state (Potomac, Rappahannock, York, James) drain to the Chesapeake Bay and the Atlantic Ocean. The rivers in southeastern Virginia (Roanoke and Chowan, along with the Albemarle Basin) drain to Albemarle Sound in North Carolina. The southwestern rivers (New, Holston, Clinch, Powell, Big Sandy) eventually drain to the Mississippi River and the Gulf of Mexico.

Figure 3-5 shows the current status of FEMA floodplain maps in Virginia. A majority of communities only have paper Flood Insurance Rate Maps (FIRMs), although FEMA Region III and the Virginia Department of Conservation and Recreation (DCR) is taking part on Map Modernization efforts, which aim to have the entire national with Digital FIRMs (DFIRMs) by 2009. Since digital floodplain boundaries are unavailable statewide, Figure 3-4 provides the best indication of the location of the 100-yr floodplain statewide, with water bodies denoted by lines of a uniform weight.

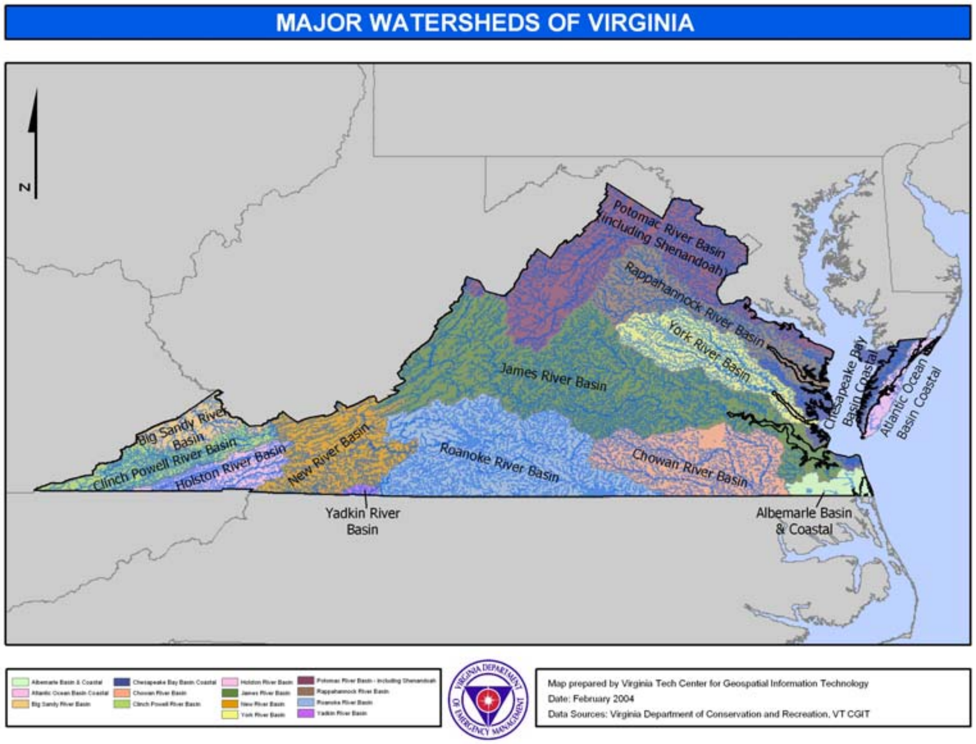


Figure 3-4 Virginia Watersheds.

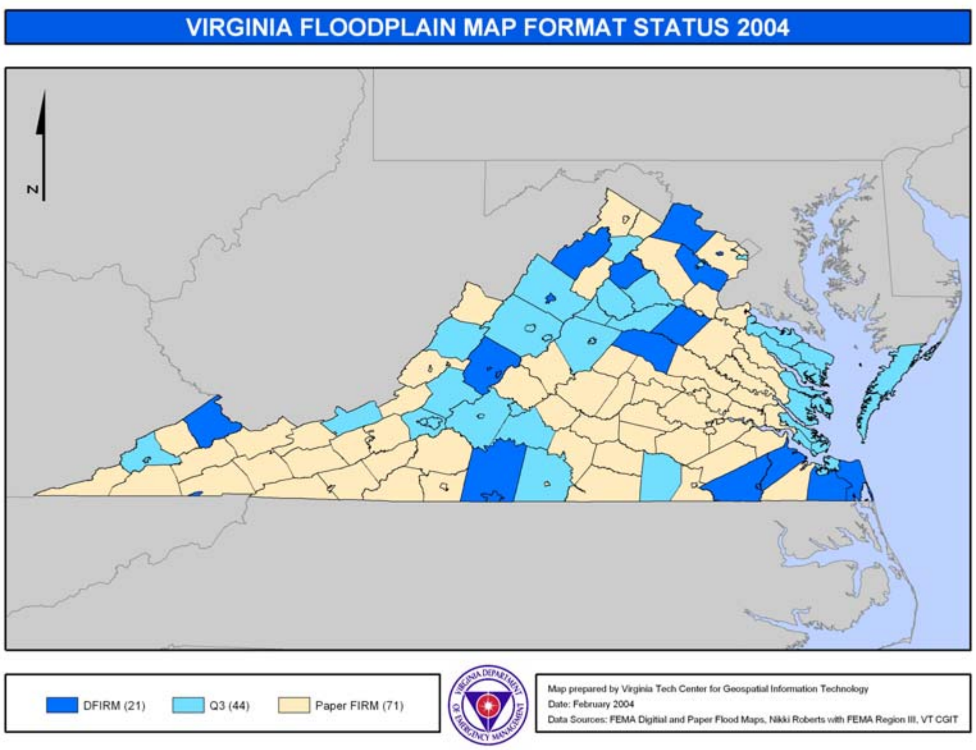


Figure 3-5 Virginia Floodplain Map Status.

Description

A flood occurs when an area that is normally dry becomes inundated with water. Floods may result from the overflow of surface waters, overflow of inland and tidal waters, or mudflows. Flooding can occur at any time of the year, with peak hazards in the late winter and early spring. Snowmelt and ice jam breakaway contribute to winter flooding, and torrential rains from hurricanes and tropical systems, and seasonal rain patterns contribute to spring flooding.

Flooding is one of the most common hazards that occur in Virginia. In the 35 years of federal disaster programs, 15 of the 23 major disasters in Virginia have been caused by floods (or hurricanes resulting in floods).

Floods typically are characterized by frequency, for example the “1%-annual chance flood,” commonly referred to as the “100-year” flood. While more frequent floods do occur, as well as larger events that have lower probabilities of occurrence, for most regulatory and hazard identification purposes, the 1%-percent annual chance flood is used.

Impacts

Homes and business may suffer damage and be susceptible to collapse. Floods pick up chemicals, sewage, and toxins from roads, factories, and farms, therefore any property affected by the flood may be contaminated with hazardous materials. Debris from vegetation and man-made structures may also be hazardous following the occurrence of a flood. In addition, floods may threaten water supplies and water quality, as well as initiate power outages.

Measures of Magnitude

In the late 1960s and early 1970s, the federal government identified counties, cities, and towns in Virginia that have some level of flood risk. In the following years, production of flood hazard maps became a significant focus of the National Flood Insurance Program. The maps, known as FIRMs for Flood Insurance Rate Maps, are the best available source to delineate areas subject to flooding.

It is notable that many FIRMs are more than 20 years old, and that flooding can and does occur outside of the flood hazard areas. Older maps may not reflect manmade alterations to floodplains caused by development activities such as filling, excavation, or grading. Perhaps more significant is that upland watershed development is not accounted for on older maps. Development increases the amount of impervious areas and alters drainage patterns, which result in increased runoff and may increase flood hazards.

Riverine and coastal flooding poses significant risk to Virginia. Given the frequency of flooding throughout the state, and the extent of development in some parts of the low-lying tidewater area, flood damage accounts for Virginia’s most significant risk.

Although coastal erosion is a continual process, it is accelerated by flooding conditions and therefore is considered a sub-category of flood hazards. Tidal surges caused continual small levels of erosion. When hurricane produce large storm surges, often developed tidal areas with insufficient protection (dunes, armoring, jetties) will cause major acceleration of the national process.

Coastal Flood Hazards

Coastal flooding occurs when strong onshore winds push water from an ocean, bay or inlet onto land. Coastal flooding may arise from tropical cyclones (hurricanes and tropical storms) or Nor'easters (extratropical storms). In Virginia the Tidewater area is highly susceptible to coastal storms, and much of the Eastern Shore is less than 6 feet above mean sea level (MSL). The highest historical storm surge recorded at Norfolk was 8 feet above mean sea level during the 1933 hurricane. The March 1962 Nor'easter drove water to 7.4 feet above MSL.

Riverine Flood Hazards

Virginia has more than 27,000 miles of rivers and streams. All of these waterways have floodplains subject to inundation. Combining a 1987 estimate prepared by FEMA with other estimates from rural areas, the Plan's authors suggest that a "reasonable approximation of the total area that is subject to flooding by the 100-year flood would be 10 percent of the state or 3,970 square miles." Virginia partners with the National Weather Service and adjacent states to manage the Integrated Flood Observing and Warning System (IFLOWS), a wide area monitoring and communications network designed to improve local flash food warnings.

<u>Additional Information</u>

The FEMA Map Service Center website, http://store.msc.fema.gov/, provides access to currently available FEMA floodplain mapping. VDEM also maintains historical flood information in their library at http://www.vdem.state.va.us/library/.

Proposed projects (Information and Data Development: Identify data needs and sources and Identify data analysis methods) for flooding and natural hazards information would provide data for future analysis in upcoming plans. Projects include: 3.1.1 Climate and Natural Hazard Information Collection; 3.1.2 Establish and Maintain the Virginia Mitigation Database; 3.1.4 Real Time Flood Inundation Mapping Program; 3.2.2 Update 100 and 500 year Flood Frequency statistics. Additional information regarding the projects can be found in Appendix H. In addition, as mentioned earlier, FEMA is undertaking their Flood Map Modernization program to update all floodplain mapping, include Virginia's, by 2009.

High Wind/Windstorm (Including Thunderstorms and Lightning)

Historic Occurrence

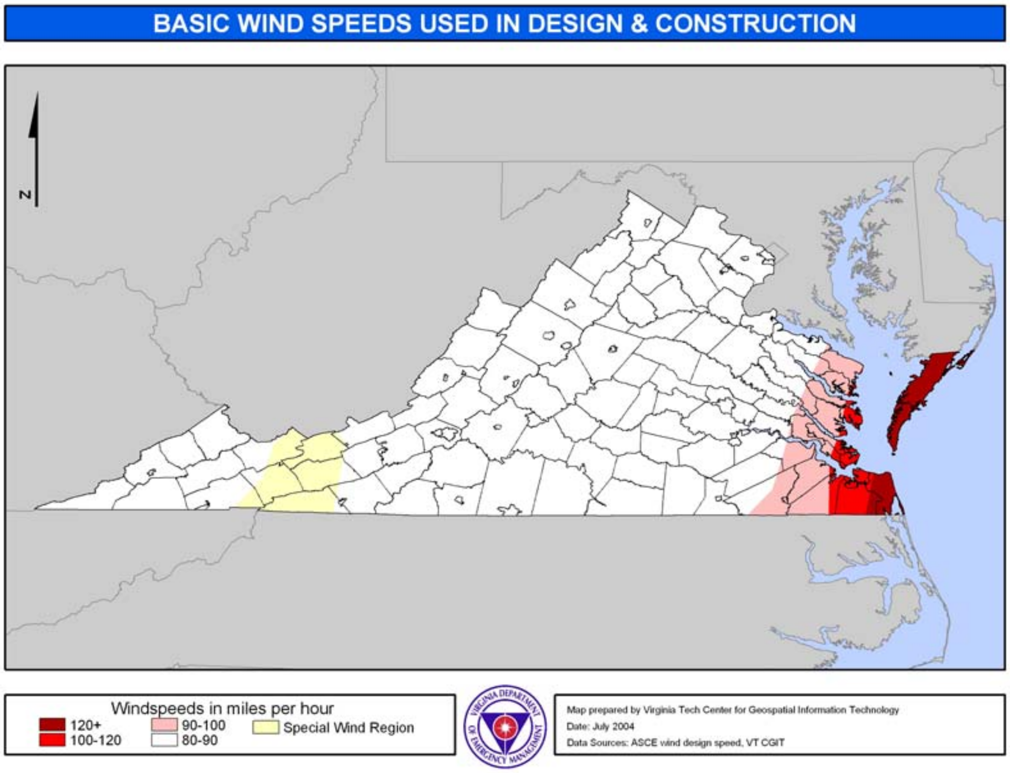


Figure 3-6. 50-yr Design Wind Speeds for Virginia (from ASCE 7-98).

Figure 3-6 shows the basic design wind speed used for design and construction in Virginia. This map not only applies to windstorms, but also hurricane winds and tornado winds, as a basis for structural design based on potential wind loads.

Most severe windstorms, thunderstorms, and lightning events are very localized and have not been documented. The NOAA National Climatic Data Center, http://www.ncdc.noaa.gov/oa/ncdc.html, has recently developed an online Storm Events database with some information about windstorms, thunderstorms, and lightning. The database included the following about Virginia:

- From the period of 1959 through 2000 lightning accounted for 58 fatalities and 208 injuries in Virginia. During 1995 through 2000 lightning accounted for approximately $6.5 million of damages.
- September 4, 1993. Southeast Virginia. Thunderstorms in southeast Virginia caused damage to homes and power lines. Golf ball sized hail was reported in Newport News, Property damages were estimated at $5 million.
- May 26, 1994 Hampton Roads area. A severe thunderstorm produced extensive structural damage. Power was knocked out to 10,700 people. Property damage was estimated at $5 million.

- June 12, 2000. Rockingham County. A thunderstorm which contained very heavy rainfall moved across the county. A large tent at the Rockingham County Fairgrounds collapsed under the weight of the deluge, resulting in $150, 000 of damages.

According to the NWS, Virginia averages 35 to 45 thunderstorm days per year. Thunderstorms can occur any day of the year and at any time of the day, but are most common in the late afternoon and evening during the summer months. A majority of the deaths and injuries from lightning in Virginia have occurred from May-September, with the most during July. About five percent of thunderstorms become severe and can produce tornadoes, large hail, damaging downburst winds, and heavy rains causing flash floods. All thunderstorms produce lightning which can be deadly. The National Weather Service does not issue warnings for ordinary thunderstorms nor for lightning.

Description

High windstorms, thunderstorms and lightning occasionally produce sustained winds or wind gusts that exceed 55 mph and produce damage (e.g. downed trees/power lines, structural damage to homes/businesses, etc.). Occasional severe storms can occur, developing in less than 30 minutes, and can produce heavy rains and flash flooding, damaging winds, tornadoes and hail. Such events are generally localized in nature, but occur on an annual basis in the Commonwealth. Damaging winds are generally not considered life threatening, but deaths and injuries have occurred in Virginia. Widespread and significant damaging wind events are a rare occurrence in Virginia.

Impact

Damaging winds (thunderstorms) are an annual threat for the commonwealth. Occurrences of a widespread thunderstorm producing damaging winds are rare (once every 2-3 years). The National Weather Service (since 1955) has recorded occurrences of thunderstorm produced wind damage.

Measures of Magnitude

Occasionally, corridors of thunderstorms will cause widespread, usually minor damage. In very rare cases, thunderstorm winds can exceed 100 mph, and produce damage comparable to an F2 tornado. The threats posed by an individual thunderstorm producing damaging winds are localized in nature, and generally affect an area less than 200 square miles.

Additional Information

Information about windstorms and thunderstorms can be found at the website for the NOAA Storm Prediction Center at http://www.spc.noaa.gov/software/svrplot2/ and at the NOAA National Climatic Data Center at http://www.ncdc.noaa.gov/oa/ncdc.html.

Proposed projects (Information and Data Development: Identify data needs) for high windstorms/thunderstorms/lightning and natural hazards information would provide data for future analysis in upcoming plans. Projects include: 3.1.1 Climate and Natural Hazard Information Collection; 3.1.2 Establish and Maintain the Virginia Mitigation Database. Additional information regarding the projects can be found in Appendix H.

Hurricanes, including Tropical Depressions and Storms

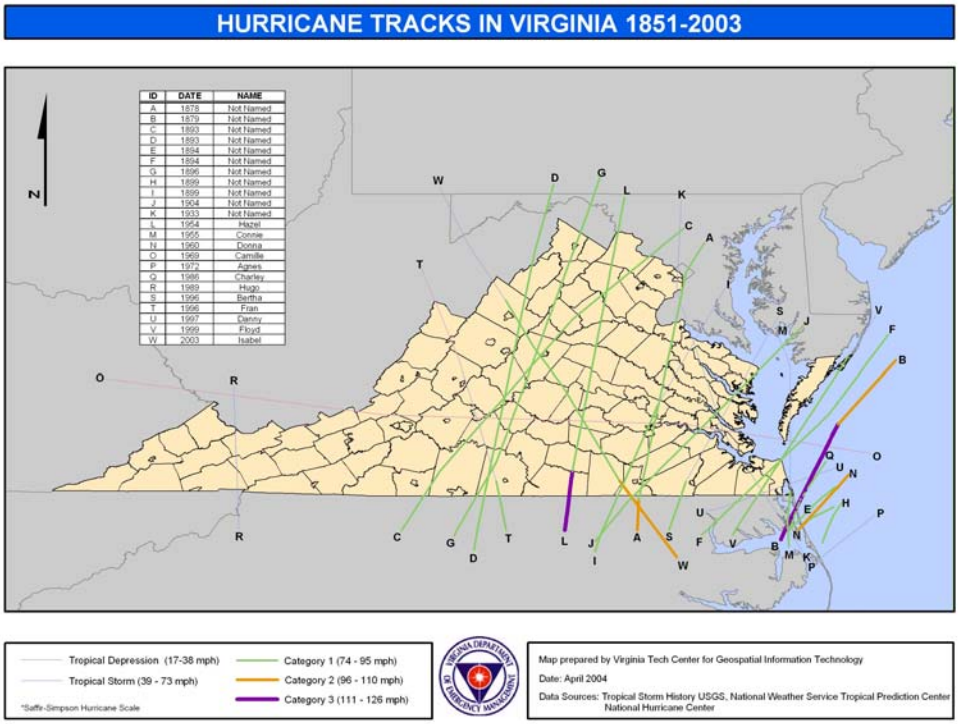


Figure 3-7. Major Virginia Hurricane Tracks 1851-2003 with Selected Tropical Depressions and Storms.

Figure 3-7 shows the location of the major hurricanes that have impact Virginia in the last 150 years. Most of these tracks have occurred east of the mountains, in central and eastern Virginia. Storms typically track to the northeast, with the notable exceptions of Camille (Track O), Hugo (Track R), Fran (Track T), and Isabel (Track W).

<u>Description</u>

Any weather development that begins over tropical waters and is characterized by significant rainfall and circulating winds around a low pressure center is defined as a tropical cyclone. A tropical cyclone with wind speed of less than 39 miles per hour is identified as a tropical depression. When the wind speed exceeds 39 miles per hour, but less than 75, the storm is designated as a Tropical Storm. Any storm winds 75 mph or higher is classified as a Hurricane. The low pressure center, or the “eye” of the storm, can range in size from 10 to 30 nautical miles in diameter. The surrounding storm can range anywhere from 100 to 500 nautical miles across.

Tropical Storms and Hurricanes are fueled by warm waters, thus the season for these storms begin June 1 and end November 30. Peak times for Virginia are in August and September when the Atlantic Ocean waters are the warmest. By default, once a storm system reaches land or cooler waters the storm strength lessens and the storm begins to dissipate.

Impacts

Tropical cyclones involve both atmospheric and hydrologic characteristics, such as severe winds, storm, surge flooding, high waves, coastal erosion, extreme rainfall, thunderstorms, lightning, and, in some cases, tornadoes. Storm surge flooding can push inland, and riverine flooding associated with heavy inland rains can be extensive. Many areas of the Tidewater region are flat, and intense prolonged rainfall tends to accumulate without ready drainage paths. High winds are also associated with hurricanes, with two significant effects: widespread debris due to damaged and downed trees and building debris; and power outages. The Tidewater region, including areas on tidal-influenced tributaries, is vulnerable to hurricanes and their effects.

As the storm moves into more shallow waters, the waves lessen, but water levels rise, bulging up on the storm's front right quadrant in what is called the "storm surge." This is the deadliest part of a hurricane. The storm surge and wind driven waves can devastate a coastline and bring ocean water several miles inland. Once inland, the hurricane's band of thunderstorms produces torrential rains and sometimes tornadoes. A foot or more of rain may fall in less than a day causing flash floods and mudslides. The rain eventually drains into the large rivers which may still be flooding for days after the storm has passed. The storm's driving winds can topple trees, utility poles, and damage buildings. Communication and electricity is lost for days and roads are impassable due to fallen trees and debris.

Secondary hazards from a hurricane event could include high winds, flooding, heavy waves, and tornadoes.

Measures of Magnitude

Hurricanes are categorized by the Safer-Simpson Hurricane Damage Scale listed below. Following the table are detailed descriptions of each category and the potential damage caused by each.

Table 3-5 Saffir-Simpson Hurricane Damage Scale

Hurricane Category	**Sustained Winds (mph)**	**Damage Potential**
1	74 - 95	Minimal
2	96 - 110	Moderate
3	111 - 130	Extensive
4	131 - 155	Extreme
5	> 155	Catastrophic

Category 1
A Category 1 hurricane poses minimal damage to unanchored mobile homes along with shrubbery and trees. There may be pier damage and coastal road flooding, with storm surge 4-5 feet about average.

Category 2
Category 2 hurricanes have a moderate damage potential to mobile homes and piers, as well as significant damage to shrubbery and tress with some damages to roofs, doors and windows. Impacts include flooding 2-4 hours before arrival of the hurricane in coastal and low lying areas. Storm surge can be 6-8 feet above average.

Category 3
Category 3 hurricanes have an extensive damage potential. There will be structural damage to small residences and utility buildings. Extensive damage is to mobile homes and trees and shrubbery. Impacts include flooding 3-5 hours before the arrival of the hurricane cutting off the low lying escape routes. Coastal flooding has the potential to destroy the small structures, with significant damage to larger structures as a result of the floating debris.

Land that is lower than 5 feet below mean sea level can be flooded 8 or more miles inland. Storm surge can be 6-12 feet above average.

Additional Information

The VDEM online library at **www.vdem.state.va.us/library/stats.cfm** includes an extensive background on the history and impacts of hurricanes in the Commonwealth by the National Weather Service.

Proposed projects (Information and Data Development: Identify data needs) for hurricanes and natural hazards information would provide data for future analysis in upcoming plans. Projects include: 3.1.1 Climate and Natural Hazard Information Collection; 3.1.2 Establish and Maintain the Virginia Mitigation Database. Additional information regarding the projects can be found in Appendix H.

Land Subsidence (Karst)

<u>Historic Occurrence</u>

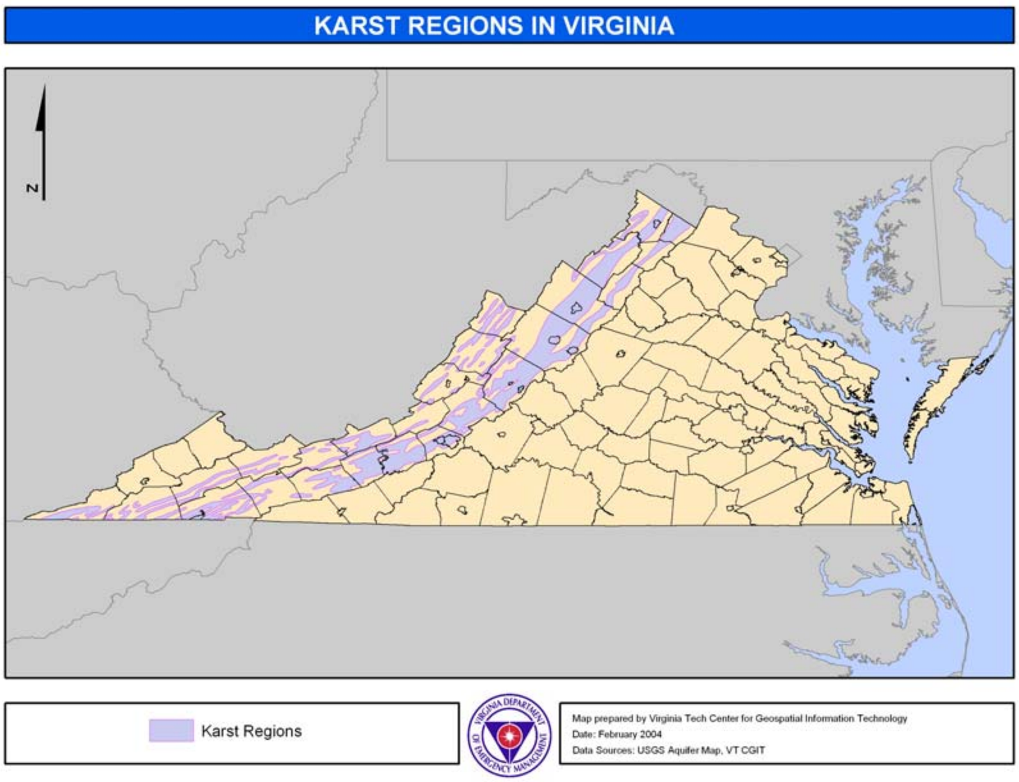


Figure 3-8. Karst Regions in Virginia.

The area of karst in Virginia, as shown in Figure 3-8, are primarily limited to the mountainous regions of the state.

Because land subsidence caused by karst is very site-specific and often occurs in undeveloped areas, there is no existing long-term record for Virginia. A few recent occurrence include the following:

- 1992 Clarke County house collapsed inside of a sinkhole after the drilling of a new well on the property.
- March 2001, Interstate 81 was closed for a nine mile stretch near Augusta County because of the sudden appearance of three sinkholes. The largest of the three sinkholes was measured at 20 feet long, 11 feet wide and 22 feet deep. Since Interstate 81 runs along the karst region of Virginia, most of the impact from sinkhole have been seen on this roadway.

<u>Description</u>

Land subsidence is the lowering of surface elevations due to changes made underground. The USGS notes that land subsidence is usually caused by human activity such as pumping of water, oil, or gas from underground reservoirs. Land subsidence often occurs in regions with mildly acidic groundwater and the geology is dominated by limestone, dolostone, marble or gypsum. Karst is the term used to refer to geology dominated by limestone and similar soluble rocks. The acidic groundwater dissolves the surrounding geology creating sinkholes.

Sinkholes are classified as natural depressions of the land surface. Areas with large amounts of karst are characterized by the presence of sinkholes, sinking streams, springs, caves and solution valleys.

Impacts

The USGS recognizes four major impacts caused by land subsidence:

- changes in elevation and slope of streams, canals, and drains
- damage to bridges, roads, railroads, storm drains, sanitary sewers, canals, and levees
- damage to private and public buildings
- failure of well casings from forces generated by compaction of fine-grained materials in aquifer systems

Measures of Magnitude

The most important current and future environmental issue with respect to karst is the sensitivity of karst aquifers to groundwater contamination. The effect of man on karst is most severe in cases where polluted surface waters enter karst aquifers. This problem is universal among all karst regions in the United States that underlie populated areas. The country's karstic groundwater problems are accelerated with the advent of (1) expanding urbanization, (2) misuse and improper disposal of environmentally hazardous chemicals, (3) shortage of suitable repositories for toxic waste (both household and industrial), and (4) ineffective public education on waste disposal and the sensitivity of the karstic groundwater system.

Occasionally the land surface in karst regions may collapse. Most of these events are triggered by man's activities in the karstic environment. Excessive pumping of groundwater from karstic aquifers may rapidly lower the water table and calls a sudden loss of buoyant forces that stabilize the roofs of cavernous openings. Man-induced changes in surface water flow and infiltration also may cause collapse. Most sinkholes that form suddenly occur where soil that overlies bedrock collapses into the pre-existing void.

More Information

More information about Virginia karst can be found at the Virginia DCR karst website at http://www.dcr.state.va.us/dnh/karsthome.htm and at the USGS website at http://nationalatlas.gov/atlasftp.html.

Proposed projects (Information and Data Development: Identify data needs) for land subsidence (karst) and natural hazards information would provide data for future analysis in upcoming plans. Projects include: 3.1.1 Climate and Natural Hazard Information Collection; 3.1.2 Establish and Maintain the Virginia Mitigation Database; 3.1.8 Produce and Accurate and Highly detailed Map of Virginia’s Karst; 3.1.9 Delineation of Watersheds and Recharge Areas for Karst Aquifers in Virginia and Compilation of a GIS based Comprehensive Karst Hydrology for Virginia. Additional information regarding the projects can be found in Appendix H.

Landslides

<u>Historical Occurrence</u>

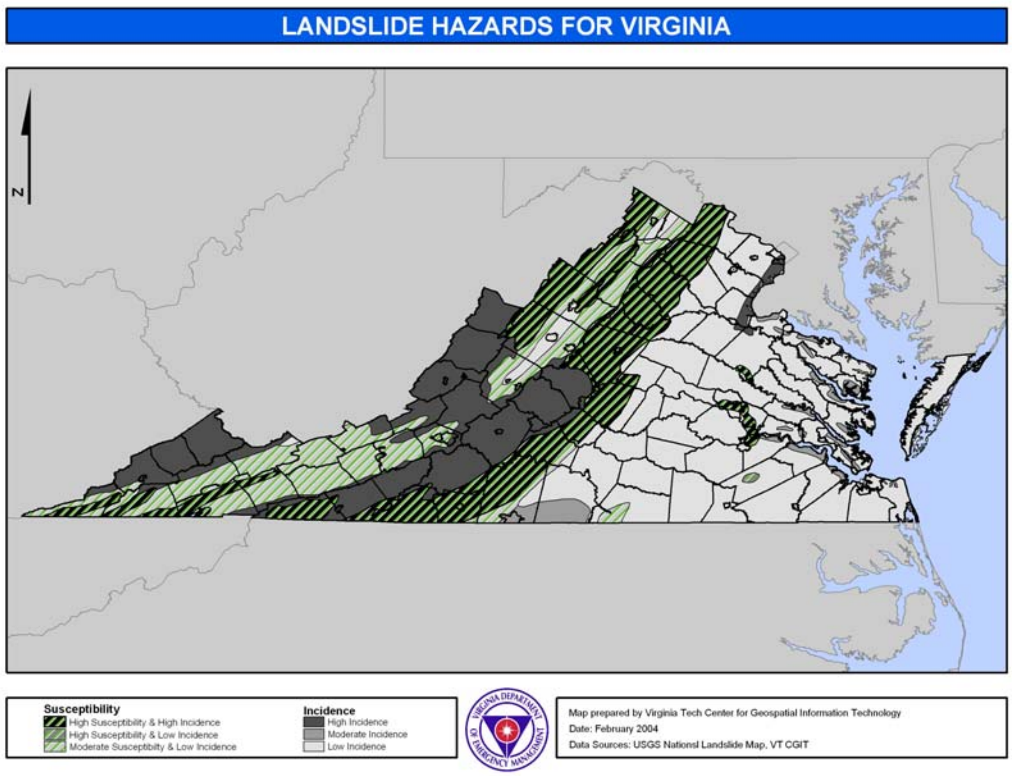


Figure 3-9. Landslide Susceptibility and Incidence in Virginia.

Similar to karst, Figure 3-9 shows that most landslide hazards are located in western and southwestern Virginia. Also like karst, there are no existing database with landslide occurrences within the state. As reported by the USGS in 1995, several notable recent landslide and debris flow in Virginia have resulted in extensive damage:

- In 1969, Hurricane Camille stalled over the Blue Ridge Mountains of Nelson County, dropping more than 30 inches of rain in under 8 hours. Flooding and numerous landslides and debris flows led to the deaths of more than 150 people, destruction of more than 100 bridges, and more than $150 million in property damage.
- Affecting both Virginia and West Virginia, a November 1985 storm in the Potomac and Cheat River watersheds produced record floods and extensive landslide and debris flow activity, causing 70 deaths and a total of $1.3 billion in damage to homes, businesses, roads, and farmlands.
- Madison County experienced hundreds of landslides in June 1995, which combined with widespread flooding killed eight people, affected as many as 2,000 homes, and damaged 35,000 acres of crops. Total property damages were estimated at $112 million.

<u>Definition</u>

The term "landslide" is used to describe the downward and outward movement of slope-forming materials reacting under the force of gravity. The term covers a broad category of events, including mudflows, mudslides, debris flows, rock falls, rock slides, debris avalanches, debris slides, and earth flows. These terms vary by the amount of water in the materials that are moving.

Several natural and human factors may contribute to or influence landslides. How these factors interrelate is important in understanding the hazard. The three principal natural factors are topography, geology, and precipitation. The principle human activities are cut-and-fill construction for highways, construction of buildings and railroads, and mining operations.

Impacts

Landslides can cause serious damage to highways, buildings, homes, and other structures that support a wide range of economies and activities. Landslides commonly coincide with other natural disasters. Expansion of urban development contributes to greater risk of damage by landslides.

Measures of Magnitude

The magnitude of landslides is dependent on the amount of liquid and landmass in motion and the amount of development in the area. Often a landslide will be more severe in areas with higher slopes with poorly draining soils.

More Information

More information about landslides can be found at the USGS website at http://nationalatlas.gov/lsoverm.html.

Proposed projects (Information and Data Development: Identify data needs) for landslides and natural hazards information would provide data for future analysis in upcoming plans. Projects include: 3.1.1 Climate and Natural Hazard Information Collection; 3.1.2 Establish and Maintain the Virginia Mitigation Database. Additional information regarding the projects can be found in Appendix H.

Tornado Including Hail

Historic Occurrence

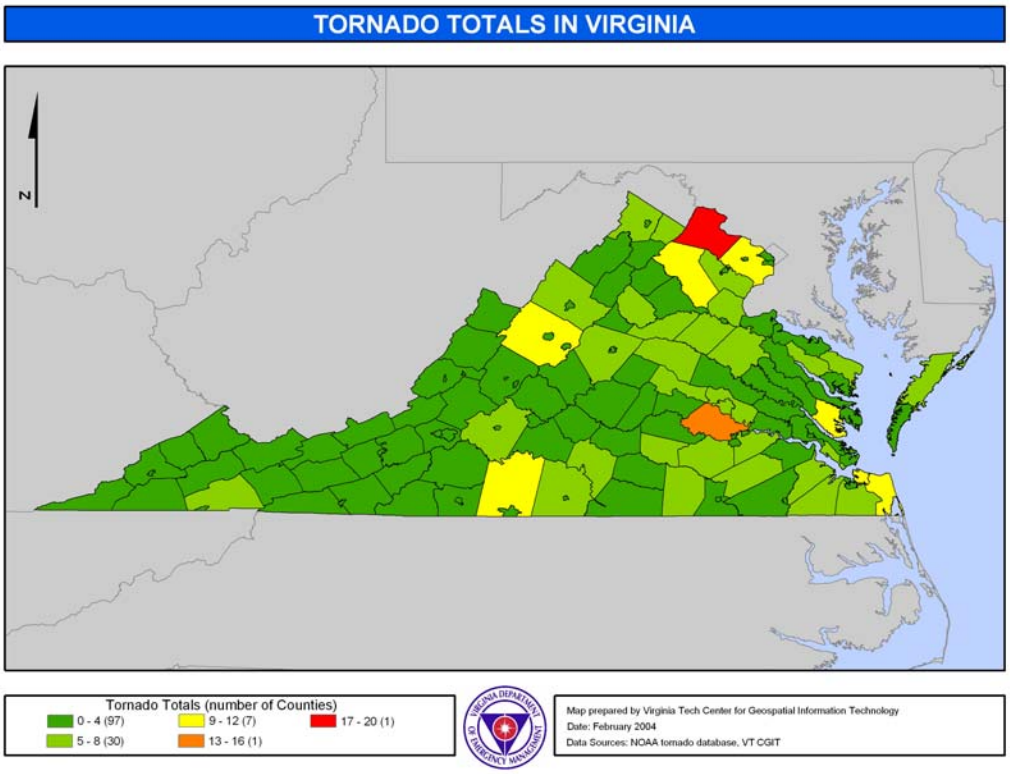


Figure 3-10. Recorded Tornado Counts from 1950-2003 in Virginia.

Figure 3-10 shows that most Virginia communities have had few tornadoes occur over the past 50 years.

The following list, based on available records from VDEM and the NWS, includes the dates of significant tornadoes in Virginia since 1900:

- September 22, 1900
- August 6, 1901
- February 21, 1912
- August 3, 1915
- October 29, 1917
- August 7, 1922
- April 29, 1923
- April 30, 1924
- November 26, 1926
- November 17, 1927
- May 2, 1929 “Virginia’s Deadliest Tornado Outbreak”
- January 5, 1931
- March 28, 1932
- September 5, 1935
- May 20, 1938
- August 19, 1939

- March 4, 1944
- May 21, 1947
- June 13, 1951 "Richmond Tornado" Property damage estimated at $250,000 (F2)
- April 5, 1952 Augusta County and Rockingham County. Property damage estimated at $275,000. (F2)
- August 31, 1952
- September 30, 1959
- September 10, 1960
- April 8, 1963
- July 12, 1964
- November 2, 1966
- July 4, 1967
- March 24, 1969
- November 3, 1971
- April 1, 1973
- April 4, 1974 "Super Outbreak" Property damage estimated over $2.5 million. (F2)
- December 1, 1974
- January 25, 1975
- April 25, 1975
- July 8, 1977
- July 19, 1977
- August 12, 1977
- January 26, 1978
- April 19, 1978
- September 5, 1979 "Hurricane David" Property damage estimated over one million dollars. (F2)
- March 30, 1981
- October 13, 1983 Property damages estimated over five million dollars. (F2)
- May 8, 1984
- July 25, 1985
- October 14, 1986
- August 29, 1988
- November 28, 1988
- April 2, 1990
- May 4, 1990
- October 18, 1990
- August 6, 1993 "Petersburg/Colonial Heights Tornado" Property damages estimated over $10 million.
- August 17, 1994 Martinsville. The thunderstorm that produced the tornado was part of the remnants of Tropical Storm Beryl. Property damages estimated over $50 million.
- October 5, 1995
- November 11, 1995
- September 6, 1996
- July 24, 1997
- April 1, 1998
- May 7, 1998
- March 3, 1999
- July 24, 1999
- September 4, 1999 Hampton City. Extensive structural damage, property damage estimated at $7.7 million. There were 6,600 people without power as a result of the tornado.
- May 13, 2000
- September 24, 2001

<u>Description</u>

Damaging winds typically are associated with tornadoes or landfalling hurricanes. Isolated “downburst” or “straight-line” winds associated with any common thunderstorm can also cause extensive property damage.

Tornadoes are classified as a rotating column of wind that extends between a thunderstorm cloud and the earth’s surface. Winds are typically less than 100 mph, with severe tornado wind speeds exceeding 250 mph. The rotating column of air often resembles a funnel shaped cloud. The widths of tornados are usually several yards across, with infrequent events being over a mile wide. Tornadoes and their resultant damage can be classified into six categories using the Fujita Scale. This scale assigns numerical values for wind speeds inside the tornado according to the type of damage and degree of the tornado. Most tornadoes are F0 and F1, resulting in little widespread damage. Tornado activity normally spans from April through July but tornados can occur at any time throughout the year. In Virginia, peak tornado activity is in July. Hot, humid conditions stimulate the tornadoes growth.

Strong tornadoes may be produced by thunderstorms and often are associated with the passage of hurricanes. On average, about seven tornadoes are reported in Virginia each year. The total number may be higher as incidents may occur over areas with sparse populations, or may not cause any property damage.

Tornadoes also produce hail. Hailstorms are also outgrowths of severe thunderstorms. During summer months, when the difference between ground and upper level temperatures is significant, hail may develop. The size of the hailstones is directly related to the severity and size of the storm. Based on average annual days with hailstorms, most areas of Virginia can expect to see fewer than two hailstorms a year. The far southwestern part of the state may have more hail generating events, as it also experiences more thunderstorms. Hail is described as chunks of ice, often in a spherical or oblong shape, that are produced by thunderstorms.

<u>Impacts and Measures of Magnitude</u>

Tornado damage is computed using the Fujita Scale, as shown in Figure 3-5. Classification is based on the amount of damage caused by the tornado, where the measure of magnitude is based on the impact.

Table 3-6. Fujita Tornado Intensity Scale (From National Weather Service)

Classification	Max. Winds (mph)	Path Length (mi.)	Path Width (mi)	Damage
F0	less than 73	less than 1.0	less than 0.01	Chimneys damaged, trees broken
F1	73-112	1.0-3.1	0.01-0.03	Mobile homes moved off foundations or overturned
F2	113-157	3.2-9.9	0.03-0.09	Considerable damage, mobile homes demolished, trees uprooted
F3	158-206	10-31	0.10-0.29	Roof and walls torn down, trains overturned, cars thrown
F4	207-260	32-99	0.30-0.90	Well-constructed walls leveled
F5	261-318	100-315	1.0-3.1	Homes lifted off foundations and carried some distance, cars thrown as far as 300 ft

The classification of the tornado gives an approximate depiction of what the corresponding damage of the tornado will be. A majority of Virginia’s tornadoes are F0 and F1 on the Fujita Scale, shown in Table 3-7. These result in minimal extensive damage. Damage that is likely to occur would be damage to trees, shrubbery, signs, antennas, with some damage to roofs and unanchored trailers.

Figure 3-7. Virginia Tornado Statistics 1950-2001

Fujita Scale	Class.	MPH	Damage Description	# in VA	%	Deaths / Injuries	Damages ($ Mil)
F0	Weak	40-72	Light damage. Tree branches snapped; antennas and signs damaged.	99	26	0 / 0	7
F1	Moderate	73-112	Moderate damage. Roofs off; trees snapped; trailers moved or overturned.	186	50	1 / 85	57
F2	Strong	113-157	Considerable damage. Weak structures and trailers demolished; cars blown off road.	66	18	3 / 72	75
F3	Severe	158-206	Roofs and some walls torn off well constructed buildings; some rural buildings demolished; cars lifted and tumbled.	23	6	19 / 102	140
F4	Devastating	207-260	Houses leveled leaving piles of debris; cars thrown some distance.	2	0.1	4 / 248	50
F5	Incredible	261-318	Well built houses lifted off foundation and disintegrated with debris carried some distance.	0	0	n/a	n/a

Virginia's most notable tornadoes in recent years struck the Petersburg and Colonial Heights area on August 6, 1993, killing four people and injuring 28 others. Based on damage, the tornadoes were F3 and F4, with maximum winds of nearly 210 mph. Major damage occurred in the Old Towne section of Petersburg, and several stores and businesses in Colonial Heights were destroyed. Other tornadoes hit the same day in the cities of Newport News and Chesapeake. Total damages were estimated to be $52.5 million, making it the most costly tornado outbreak in Virginia to date.

Damage also comes from hail. While hail occurs on an annual basis in the Commonwealth, it is generally not considered a major threat to life and property. There are, however, instances where hail can cause property/crop damage, and can be a threat to life. Very large hail (i.e. 2 inches in diameter or larger) is an uncommon occurrence, and has the greatest threat for injury and/or possible death, and an increased threat for property damage. In addition, thunderstorms which produce significant quantities of hail, regardless of size, can damage crops and forests. The threats posed by an individual hail-producing thunderstorm are localized in nature, and generally affect an area less than 200 square miles. The size of the hail greatly affects the magnitude or severity of damage. Storms can produce hail from as small as ¼ inch in diameter to up to 4 ½ inches. Depending on the size of hail determines the potential damage.

Additional Information

The VDEM online library at **www.vdem.state.va.us/library/stats.cfm** includes extensive background information on tornadoes and hail in Virginia.

Proposed projects (Information and Data Development: Identify data needs) for tornadoes and natural hazards information would provide data for future analysis in upcoming plans. Projects include: 3.1.1 Climate and Natural Hazard Information Collection; 3.1.2 Establish and Maintain the Virginia Mitigation Database. Additional information regarding the projects can be found in Appendix H.

Wildfire

Historic Occurrence

The following list, based on available records from Virginia Department of Forestry (VDOF), includes the dates of significant wildfire in Virginia since 1960:

- 1963 Historical data unavailable at this time.
- 1987 Historical data unavailable at this time.
- 1995 April 9. Fueled by dry conditions, dead trees and limbs and gusty winds. More than 66 acres of forest burned in Buckingham County; 150 acres of forest in Franklin County burned with the evacuation of 65 residents; 24 acres of forest in Pittsylvania County burned. Total property damage from the fires was greater than $50,000.
- 1999 Virginia Department of Forestry reported the Fire Season (January – July) recorded 1,320 fires burning 6,146 acres of land. Cumulative Severity Index (1 - 800 rating for fire danger) rated Northern Virginia at 628 by end of July. On April 2, fire burned over 400 acres on Afton Mountain. The fire was fueled by strong winds, dead vegetation and very dry conditions. Property damage estimated at $2,000. On July 9, White Post, Clarke County. A combine working in a wheat field overheated and started a fire which spread rapidly as a result of the extremely dry conditions. The fire destroyed the combine ($92,000) and 60 acres of wheat ($6,700), 5 acres of farmland and 2 acres of woodland. Six firefighters were treated for heat exhaustion.

Since wildfire occurrence is based on some many different factors, the VDOF developed a fire ranking map to assist to wildfire prevention efforts, as shown in Figure 3-11.

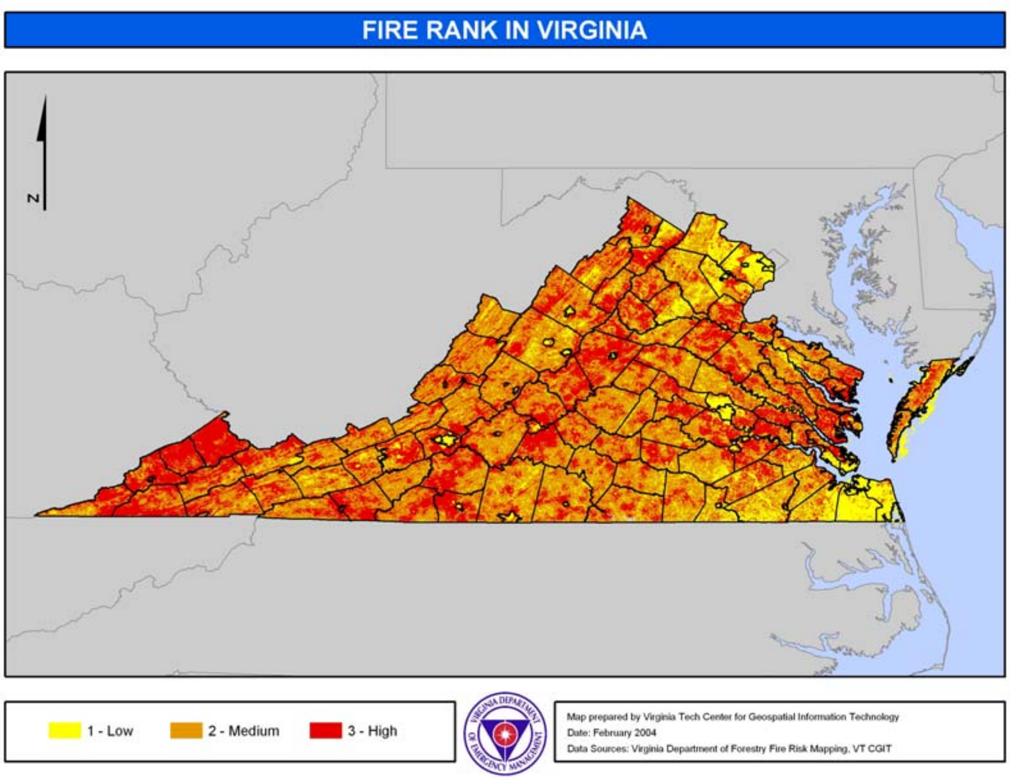


Figure 3-11. Virginia Wildfire Risk Hazard Mapping from VA Department of Forestry.

Description

Wildfire is a unique hazard in that it can be significantly altered based on efforts to control its course during the event. Spring (March and April) and fall (October and November) are the two seasons for wildfires. The Virginia Department of Forestry (VDOF) indicates that there are three principle factors that can lead to the formation of wildfire hazards: topography, fuel, and weather. The environmental conditions that exist during these seasons exacerbate the hazard. When relative humidity is low and high winds are coupled with a dry forest floor (brush, grasses, leaf litter), wildfires may easily ignite. Years of drought can lead to environmental conditions that promote wildfires. In Virginia, accidental or intentional setting of fires by humans is the largest contributor to wildfires. Residential areas that expand into wildland areas also increase the risk of wildfire threats.

Impacts

The impacts of wildfires can be widespread leading to many secondary hazards. During a wildfire, the removal of groundcover that serves to stabilize soil can lead to hazards such as landslides, mudslides, and flooding. In addition, the leftover scorched and barren land may take years to recover and the resulting erosion can be problematic.

Measures of Magnitude

Figure 3-11 shows the wildfire hazard map developed by VDOF. In 2002 and 2003, VDOF examined which factors influence the occurrence and advancement of wildfires and how these factors could be represented in a GIS model. VDOF determined that historical fire incidents, land cover (fuels surrogate), topographic characteristics, population density, and distance to roads were critical variables in a wildfire risk analysis. The resulting high, medium, and low risk category reflect the results of these analysis.

Additional Information

The VDOF website, http://www.dof.virginia.gov/gis/, has more information about wildfire hazards and their mapping and prediction.

Proposed projects (Information and Data Development: Identify data needs) for wildfires and natural hazards information would provide data for future analysis in upcoming plans. Projects include: 3.1.1 Climate and Natural Hazard Information Collection; 3.1.2 Establish and Maintain the Virginia Mitigation Database; 3.1.10 Hazard Mitigation for Virginia Department of Fire Programs. Additional information regarding the projects can be found in Appendix H.

3.3 *Assessing Vulnerabilities*

After identifying hazards in the Commonwealth and gathering background information, the next step in the HIRA was assessing vulnerabilities. DMA 2000 states the following:

> *§201.4(c)(2)(ii) [The state plan shall have] An overview and analysis of the State's vulnerability to the hazards described in this paragraph (c)(2), based on estimates provided in local risk assessments as well as the State risk assessment. The State shall describe vulnerability in terms of the jurisdictions most threatened by the identified hazards, and most vulnerable to damage and loss associated with hazard events. State owned critical or operated facilities located in the identified hazard areas shall also be addressed;*

As mentioned at the beginning the chapter, no completed local plans were available to use as part of this Virginia Plan. Therefore, all vulnerability assessments made exclusive use of information gathered for the statewide plan. Appendix G contains information about the current status of the local plans. The following subsections in this chapter will give the background information about the vulnerably assessment techniques used, followed by the jurisdiction analysis and the state facility analysis (including critical facilities).

The next update to this plan in 2007 will include information from local risk assessments, which will be included in the new Mitigation Database (Project 3.1.2 Establish and Maintain the Virginia Mitigation Database in Appendix H).

Vulnerability Assessment Techniques

Probability versus Relative Risk

A major distinction was made in this Plan between hazards that had known, established techniques for assigning hazard probability and those that had less specific hazard recurrence information. For example, FEMA floodplain maps provide 100-yr recurrence interval location for flooding, while USGS landslide mapping give general indications of landslide susceptibility or occurrence. Table 3-8 details whether probabilistic or relative risk for each HIRA analysis type.

Table 3-8. HIRA Hazard Analysis Overview

Hazard	Analysis Name	Vulnerability Method	Technique
Blizzard (Winter Storm)	Winter Storm	Relative Risk	Kaiser-Permanente
Earthquake	None	None	None
Flooding (Riverine & Coastal)	Flood	Flood Policies/Probability	GIS Intersection
Hurricane (Wind)	Wind	Probability	GIS Intersection
Land Subsidence (Karst)	Karst	Relative Risk	Kaiser-Permanente
Landslide	Landslide	Relative Risk	Kaiser-Permanente
Tornado (Wind)	Tornado	Probability	Tornado Statistics
Wildfire	Wildfire	Relative Risk	Kaiser-Permanente

Note: Flooding vulnerability method refers to flood policies being used for the jurisdictional analysis and probability used for the state facility analysis.

For some hazards, such as hurricane wind, probabilistic methods were used intersecting locations of interest with mapping within a GIS. For other hazards, a relative risk method was used based on a tool developed by Kaiser Permanente.

Kaiser-Permanente Relative Risk Technique

Table 3-9 shows the use of a relative risk technique developed by Kaiser-Permanente (KP).

Table 3-9. Kaiser-Permanente Technique for Relative Risk Assessment

COMMONWEALTH OF VIRGINIA HAZARD AND VULNERABILITY ASSESSMENT TOOL
NATURALLY OCCURRING EVENTS

EVENT		PROBABILITY	HUMAN IMPACT	PROPERTY IMPACT	BUSINESS IMPACT	PREPARED-NESS	INTERNAL RESPONSE	EXTERNAL RESPONSE	UNMITIGATED RISK	UNMITIGATED RANKING	MITIGATED RISK	MITIGATED RANKING
			SEVERITY = (MAGNITUDE - MITIGATION)									
		Likelihood this will occur	*Possibility of death or injury*	*Physical losses and damages*	*Interruption of services*	*Preplanning*	*Time, effectiveness, resources*	*Community / Mutual Aid staff and supplies*	*Relative Threat (w/out preparedness)*	*Based only on probability and threat*	*Relative threat* (w/magnitude and mitigation)*	*Based on probability, magnitude, & mitigation*
SCORE	EOP Volume(s)	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = High 2 = Moderate 3 = Low or none*	*0 = N/A 1 = High 2 = Moderate 3 = Low or none*	*0 = N/A 1 = High 2 = Moderate 3 = Low or none*	*0 - 100%*		*0 - 100%*	
Blizzards/Icestorms/Winter Storms	6, 7	2	2	2	3	2	2	2	52%	2	48%	3
Coastal/Shoreline Erosion	1, 5, 6	2	1	2	1	2	2	2	30%	15	37%	10
Dam Failure	1, 6	1	2	2	2	2	2	2	22%	23	22%	26
Drought	6	2	1	1	2	2	2	2	30%	15	37%	10
Earthquake	6	1	1	2	2	3	2	2	19%	28	22%	26
Flooding-Coastal	2, 5, 6	2	1	2	2	2	2	1	37%	9	37%	10
Flooding-Riverine	2, 5, 6, 7	3	2	2	2	2	1	2	67%	1	61%	1
High Wind / Windstorms	2, 5, 6	2	1	2	1	2	2	2	30%	15	37%	10
Hurricanes, generally	2, 5, 6, 7	2	2	2	2	1	2	2	44%	3	41%	8
Tropical Depressions	5, 6, 7	2	1	1	1	1	1	2	22%	23	26%	22
Tropical Storms	5, 6, 7	2	1	2	2	2	1	2	37%	9	37%	10
Hurricanes, Category 1	2, 5, 6, 7	2	2	2	2	1	2	2	44%	3	41%	8
Hurricanes, Category 2	2, 5, 6, 7	2	2	2	2	2	2	2	44%	3	44%	4
Hurricanes, Category 3	2, 5, 6, 7	1	2	3	3	2	2	2	30%	15	26%	22
Land Subsidence/Karst	6	1	1	1	1	2	2	2	11%	30	17%	30
Landslides	6	1	1	1	1	2	2	2	11%	30	17%	30
Northeasters	4, 6, 7	2	1	1	1	2	2	2	22%	23	33%	17
Tornadoes, generally	2, 6	2	2	2	2	2	2	2	44%	3	44%	4
Tornadoes, F0	2, 6	2	2	1	1	2	2	2	30%	15	37%	10
Tornadoes, F1	2, 6	2	2	2	2	2	2	2	44%	3	44%	4
Tornadoes, F2	2, 6	1	2	2	2	2	2	2	22%	23	22%	26
Wildfire	1, 6	2	2	2	2	2	2	2	44%	3	44%	4
AVERAGE SCORE		1.61	1.64	1.82	1.85	1.94	1.91	1.97	32%		33%	

**Threat increases with percentage.*

UNMITIGATED RISK=	PROBABILITY * MAGNITUDE		
	0.32	0.54	0.59

MITIGATED RISK =	PROBABILITY * SEVERITY		
	0.33	0.54	0.62

***This calculation requires data to be entered into the green Preparedness columns to have an accurate assessment.**

Spreadsheet developed by: KAISER PERMANENTE.

Modifications by: VIRGINIA DEPARTMENT OF EMERGENCY MANAGEMENT

Revised: 3/25/04

First, the probability of a hazard is assigned a low, medium, or high value. Then the severity of this hazard is evaluated based on magnitude and mitigation. Magnitude relates to impact on people, property, and businesses. Mitigation relates to preparedness, internal response and external response. The final columns give the unmitigated and mitigation relative risks for each hazard. The different scores shown in Table 3-9 for each hazard were developed by VDEM as part of the Emergency Management Accreditation Program (EMAP) process in Spring 2004.The mitigated relative risks shown in Table 3-9 were used to develop the high (purple), medium (yellow), and low (blue) relative risk categories shown in Table 3-2. A version of this technique was used for all relative risk hazard analyses, where the probability was not known precisely, but could be assigned a high, medium, or low value.

<u>Winter Storm Analysis</u>

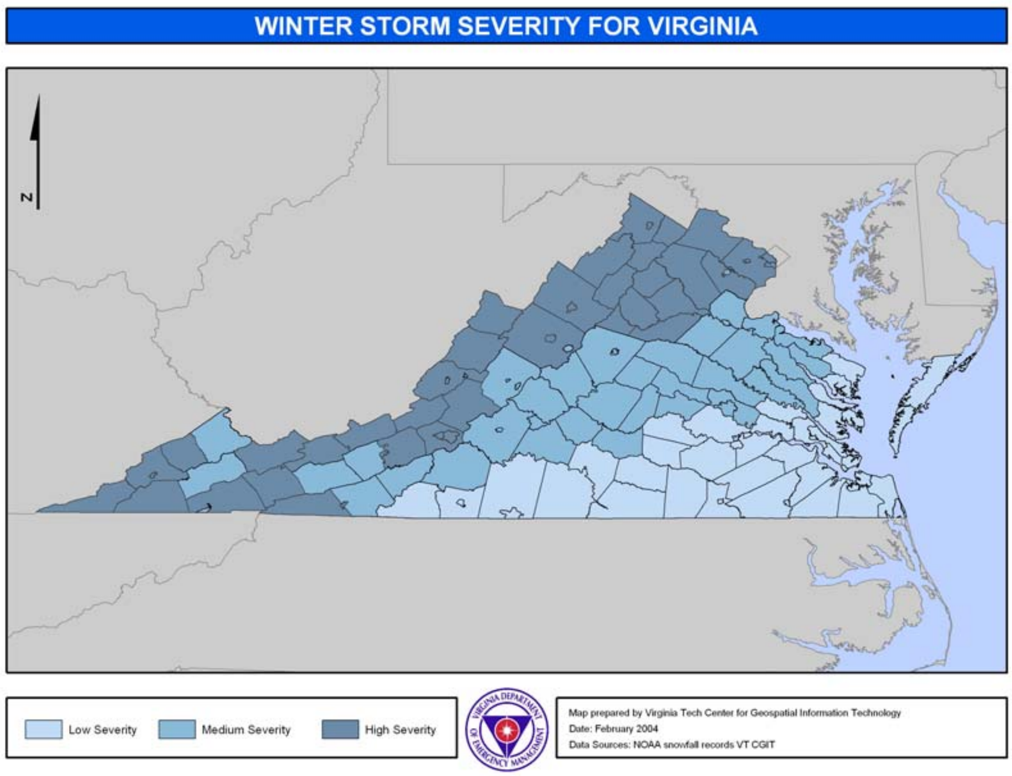


Figure 3-12. Winter Storm Relative Severity Based in Annual Snowfall Statistics.

The KP technique was used for winter storm vulnerability analysis. Figure 3-12 shows where Virginia counties and cities are split into 3 severity values based on annual snowfall statistics. These values were used for both the jurisdictional analysis and the state facility analysis. Table 3-10 shows the values for each jurisdiction for winter storm hazards, along as other hazards.

<u>Earthquake Analysis</u>

Table 3-7 shows no analysis being conducted for earthquake hazards in Virginia. Although there is some variation on predicted earthquake severity, this does not translate into building codes (I-Codes) with different building standards within Virginia. The typical minimum design standards in Virginia provide adequate protection from the infrequent earthquakes in the state. Therefore, VDEM decided to remove earthquakes from the HIRA analysis for jurisdictions and state facilities.

Table 3-10. Hazard Severity for Virginia Jurisdictions.

COMMUNITY_	POP 2000	HOUSE HOLDS_ 2000	Wint. KP	# FloodPol. 01/04	Wind 90 MPH Prob	Karst KP	Land slide KP	Tornado Prob	Wild-fire KP
ACCOMACK COUNTY	32095	12653	1	3415	0.216	0.000	1.000	1.254E-05	1.893
ALBEMARLE COUNTY	81066	24433	2	127	0.020	1.000	2.827	1.692E-05	2.542
ALEXANDRIA	119130	53280	3	1629	0.020	0.000	2.935	1.374E-04	1.011
ALLEGHANY COUNTY	12117	4942	3	3542	0.020	2.164	1.000	0.000E+00	2.296
AMELIA COUNTY	10830	3131	1	9	0.020	0.000	1.000	1.330E-04	2.050
AMHERST COUNTY	30616	9827	2	36	0.020	1.000	3.000	0.000E+00	2.383
APPOMATTOX COUNTY	13480	4531	2	6	0.020	0.000	2.470	1.712E-07	2.276
ARLINGTON COUNTY	175361	78520	3	187	0.020	0.000	1.679	0.000E+00	1.046
AUGUSTA COUNTY	61921	19781	3	240	0.020	2.457	1.910	5.095E-05	2.060
BATH COUNTY	4944	1895	3	32	0.020	2.249	3.000	0.000E+00	2.198
BEDFORD	6808	2475	2	3	0.020	1.000	3.000	0.000E+00	2.464
BEDFORD COUNTY	58483	17292	2	65	0.020	1.000	3.000	2.643E-05	2.222
BLAND COUNTY	6795	2244	3	58	0.020	2.211	1.000	0.000E+00	2.175
BOTETOURT COUNTY	29668	9148	3	199	0.020	2.449	2.896	0.000E+00	2.248
BRISTOL	16460	7591	2	62	0.020	2.960	2.200	2.228E-02	2.426
BRUNSWICK COUNTY	18442	5499	1	12	0.020	0.000	1.000	1.839E-04	1.961
BUCHANAN COUNTY	28014	11061	2	384	0.020	1.000	3.000	2.611E-06	2.882
BUCKINGHAM COUNTY	14884	4341	2	6	0.020	0.000	2.404	1.315E-05	2.134
BUENA VISTA	6390	2404	2	75	0.020	2.863	1.308	0.000E+00	2.139
CAMPBELL COUNTY	50591	17952	2	32	0.020	0.000	2.543	1.422E-05	2.456
CAROLINE COUNTY	22269	6631	2	27	0.020	0.000	1.184	2.184E-05	2.239
CARROLL COUNTY	27835	10463	2	19	0.020	1.000	3.000	4.508E-06	2.510
CHARLES CITY COUNTY	7359	2161	1	11	0.020	0.000	1.102	2.891E-07	2.418
CHARLOTTE COUNTY	12505	4312	1	3	0.020	0.000	1.000	2.194E-04	2.093
CHARLOTTESVILLE	36557	16009	2	41	0.020	1.000	3.000	6.692E-04	1.283
CHESAPEAKE	206316	51965	1	7108	0.133	0.000	1.000	2.768E-05	1.108
CHESTERFIELD COUNTY	256665	73441	1	309	0.020	0.000	1.124	1.023E-04	2.299
CLARKE COUNTY	13026	4236	3	49	0.020	2.631	1.332	3.393E-05	1.973
COLONIAL HEIGHTS	16163	6363	1	86	0.020	0.000	1.750	0.000E+00	1.651
COVINGTON	6747	2998	2	127	0.020	1.000	3.000	0.000E+00	1.884
CRAIG COUNTY	4986	1676	3	61	0.020	2.100	2.575	0.000E+00	2.195
CULPEPER COUNTY	34073	9757	3	29	0.020	0.000	2.079	3.106E-05	1.864
CUMBERLAND COUNTY	7892	2813	2	37	0.020	0.000	1.000	1.016E-05	2.044
DANVILLE	50076	21712	1	68	0.020	0.000	1.907	0.000E+00	1.838
DICKENSON COUNTY	16535	6457	3	91	0.020	1.000	3.000	3.887E-06	2.801
DINWIDDIE COUNTY	25886	7492	1	16	0.020	0.000	1.000	8.779E-05	1.903
EMPORIA	5580	2031	1	47	0.020	0.000	1.000	1.274E-02	1.730
ESSEX COUNTY	9112	3258	2	135	0.020	0.000	1.082	0.000E+00	1.995
FAIRFAX	20715	7362	3	224	0.020	0.000	1.000	0.000E+00	1.049
FAIRFAX COUNTY	961877	292345	3	1479	0.020	0.000	1.347	2.419E-04	1.536
FALLS CHURCH	10086	4195	3	60	0.020	0.000	1.000	2.298E-04	1.000
FAUQUIER COUNTY	56435	16509	3	100	0.020	1.000	2.139	3.043E-05	1.864
FLOYD COUNTY	13415	4763	2	11	0.020	1.000	2.984	3.016E-07	2.096
FLUVANNA COUNTY	20401	4518	2	30	0.020	0.000	1.416	4.445E-04	2.217

COMMUNITY_	POP 2000	HOUSE HOLDS_ 2000	Wint. KP	# FloodPol. 01/04	Wind 90 MPH Prob	Karst KP	Land slide KP	Tornado Prob	Wild-fire KP
FRANKLIN	7934	3006	1	161	0.031	0.000	1.000	1.077E-04	1.908
FRANKLIN COUNTY	45868	14655	2	96	0.020	1.000	3.000	0.000E+00	2.456
FREDERICK COUNTY	57678	16470	3	67	0.020	2.331	2.211	2.420E-05	2.395
FREDERICKSBURG	18374	7450	2	181	0.020	0.000	1.111	2.172E-04	1.897
GALAX	6393	2750	3	0	0.020	1.000	3.000	0.000E+00	2.951
GILES COUNTY	16346	6461	3	102	0.020	2.399	1.481	0.000E+00	2.208
GLOUCESTER COUNTY	36051	10966	1	1037	0.060	0.000	1.133	5.514E-05	2.546
GOOCHLAND COUNTY	17952	4880	2	17	0.020	0.000	1.000	1.647E-05	2.234
GRAYSON COUNTY	16489	6468	3	22	0.020	1.000	3.000	0.000E+00	2.288
GREENE COUNTY	15277	3749	3	21	0.020	1.000	3.000	8.108E-05	2.426
GREENSVILLE COUNTY	11308	3150	1	4	0.020	0.000	1.000	6.628E-05	1.663
HALIFAX COUNTY	29883	10728	1	48	0.020	0.000	1.411	8.021E-06	2.113
HAMPTON	137069	49673	1	9626	0.091	0.000	1.232	7.747E-05	1.250
HANOVER COUNTY	88325	22628	2	58	0.020	0.000	1.031	1.749E-04	1.950
HARRISONBURG	34376	10310	3	97	0.020	2.999	1.286	0.000E+00	1.658
HENRICO COUNTY	246589	89138	2	421	0.020	0.000	1.679	1.114E-04	1.868
HENRY COUNTY	55424	21771	1	88	0.020	0.000	2.900	5.989E-05	2.559
HIGHLAND COUNTY	2462	1081	3	22	0.020	2.313	3.000	0.000E+00	1.992
HOPEWELL	22453	9014	1	27	0.020	0.000	3.000	8.922E-03	1.472
ISLE OF WIGHT COUNTY	30091	9032	1	228	0.055	0.000	1.116	6.999E-05	1.887
JAMES CITY COUNTY	47293	12968	1	472	0.041	0.000	1.032	4.068E-05	2.194
KING AND QUEEN COUNTY	6590	2339	2	23	0.031	0.000	1.000	2.859E-05	2.154
KING GEORGE COUNTY	18143	4736	2	17	0.020	0.000	1.216	2.490E-05	2.165
KING WILLIAM COUNTY	13290	3834	2	75	0.020	0.000	1.042	1.574E-04	2.052
LANCASTER COUNTY	11361	4564	1	425	0.060	0.000	1.385	9.820E-05	2.575
LEE COUNTY	23732	9231	3	107	0.020	2.271	2.048	1.690E-06	2.458
LEXINGTON	7393	2172	2	10	0.020	2.621	1.000	0.000E+00	1.182
LOUDOUN COUNTY	167265	30490	3	255	0.020	1.000	2.260	4.571E-05	1.640
LOUISA COUNTY	25578	7427	2	18	0.020	0.000	1.000	4.589E-05	2.167
LUNENBURG COUNTY	11637	4423	1	N/A	0.020	0.000	1.000	3.477E-05	2.033
LYNCHBURG	63622	25143	2	92	0.020	0.000	3.000	0.000E+00	2.218
MADISON COUNTY	12695	4144	3	33	0.020	1.000	3.000	8.014E-06	2.357
MANASSAS	8066	2182	2	59	0.020	0.000	1.000	0.000E+00	1.499
MANASSAS PARK	34099	9481	2	10	0.020	0.000	1.000	0.000E+00	1.046
MARTINSVILLE	14757	6839	1	23	0.020	0.000	3.000	0.000E+00	2.178
MATHEWS COUNTY	9350	3530	1	1290	0.084	0.000	1.000	1.505E-04	2.184
MECKLENBURG COUNTY	31016	11244	1	29	0.020	0.000	1.000	5.153E-07	2.155
MIDDLESEX COUNTY	9891	3530	1	328	0.065	0.000	1.268	3.519E-05	2.292
MONTGOMERY COUNTY	77259	26241	3	197	0.020	2.684	1.391	1.347E-06	2.389
NELSON COUNTY	14409	4807	2	80	0.020	1.000	3.000	1.873E-07	2.495
NEW KENT COUNTY	13517	3718	1	33	0.025	0.000	1.160	5.374E-05	2.410
NEWPORT NEWS	179671	63952	1	1677	0.071	0.000	1.183	5.924E-04	1.390
NORFOLK	223565	89478	1	8532	0.115	0.000	1.000	2.249E-03	1.044

COMMUNITY_	POP 2000	HOUSE HOLDS_ 2000	Wint. KP	# FloodPol. 01/04	Wind 90 MPH Prob	Karst KP	Land slide KP	Tornado Prob	Wild-fire KP
NORTHAMPTON COUNTY	12824	5129	1	488	0.165	0.000	1.000	6.609E-06	1.808
NORTHUMBERLAND COUNTY	11819	4492	1	428	0.065	0.000	1.000	3.069E-05	2.360
NORTON	3974	1697	3	35	0.020	1.000	3.000	0.000E+00	2.877
NOTTOWAY COUNTY	15319	5244	1	0	0.020	0.000	1.000	9.818E-05	2.310
ORANGE COUNTY	26137	7930	3	19	0.020	0.000	1.609	1.532E-05	1.987
PAGE COUNTY	23280	8055	3	209	0.020	2.288	1.604	3.329E-06	2.334
PATRICK COUNTY	18659	6908	1	18	0.020	0.000	3.000	2.154E-06	2.352
PETERSBURG	34064	14730	1	88	0.020	0.000	1.273	1.841E-03	1.929
PITTSYLVANIA COUNTY	56930	20613	1	19	0.020	0.000	2.281	3.807E-05	2.058
POQUOSON	11644	3769	1	2596	0.084	0.000	1.000	0.000E+00	1.498
PORTSMOUTH	97452	38741	1	3017	0.091	0.000	1.000	2.767E-04	1.039
POWHATAN COUNTY	23285	4672	2	10	0.020	0.000	1.000	1.551E-05	2.392
PRINCE EDWARD COUNTY	19308	5373	2	41	0.020	0.000	1.006	9.152E-07	2.234
PRINCE GEORGE COUNTY	29113	8250	1	44	0.020	0.000	1.252	2.699E-04	2.446
PRINCE WILLIAM COUNTY	278554	69709	3	735	0.020	0.000	1.194	3.409E-05	1.753
PULASKI COUNTY	34427	13349	2	116	0.020	2.636	1.132	0.000E+00	2.199
RADFORD	15703	5207	3	18	0.020	2.516	1.000	0.000E+00	1.964
RAPPAHANNOCK COUNTY	7698	2496	3	38	0.020	1.000	3.000	1.075E-06	2.287
RICHMOND	188911	85337	2	188	0.020	0.000	2.190	5.546E-04	1.197
RICHMOND COUNTY	8784	2645	2	45	0.031	0.000	1.106	1.541E-05	1.914
ROANOKE	92707	41030	3	613	0.020	2.673	1.871	3.806E-04	1.387
ROANOKE COUNTY	81185	30355	3	380	0.020	2.346	2.006	8.253E-05	2.481
ROCKBRIDGE COUNTY	19779	7202	2	282	0.020	2.596	1.697	0.000E+00	2.134
ROCKINGHAM COUNTY	63085	20750	3	481	0.020	2.454	2.199	3.347E-06	2.256
RUSSELL COUNTY	28619	10641	2	82	0.020	2.226	1.568	4.369E-06	2.422
SALEM	23988	9161	3	488	0.020	3.000	1.000	0.000E+00	1.540
SCOTT COUNTY	22388	8966	3	74	0.020	2.265	1.960	1.911E-06	2.634
SHENANDOAH COUNTY	35660	12452	3	267	0.020	2.507	2.396	1.878E-05	2.190
SMYTH COUNTY	32619	12234	3	180	0.020	2.198	1.557	2.722E-05	2.298
SOUTHAMPTON COUNTY	17780	6009	1	134	0.034	0.000	1.000	1.541E-05	1.668
SPOTSYLVANIA COUNTY	90690	18945	2	104	0.020	0.000	1.067	1.386E-04	2.445
STAFFORD COUNTY	96835	19415	2	248	0.020	0.000	1.581	3.458E-05	2.370
STAUNTON	24419	9432	3	97	0.020	2.839	1.000	0.000E+00	1.767
SUFFOLK	66845	18516	1	492	0.071	0.000	1.013	4.834E-05	1.581
SURRY COUNTY	6514	2283	1	42	0.038	0.000	1.251	4.751E-05	1.991
SUSSEX COUNTY	12312	3795	1	62	0.022	0.000	1.069	9.489E-05	2.107
TAZEWELL COUNTY	46144	17309	3	359	0.020	2.138	1.526	0.000E+00	2.380
VIRGINIA BEACH	435329	135566	1	19835	0.177	0.000	1.000	3.099E-04	1.206
WARREN COUNTY	30946	9879	3	296	0.020	2.235	1.615	5.506E-05	2.538
WASHINGTON COUNTY	50072	17483	3	99	0.020	2.364	1.977	2.739E-05	2.330
WAYNESBORO	19372	7568	2	166	0.020	2.829	1.000	0.000E+00	1.596
WESTMORELAND COUNTY	16235	6057	2	200	0.020	0.000	1.140	1.162E-05	2.006

COMMUNITY_	POP 2000	HOUSE HOLDS_ 2000	Wint. KP	# FloodPo l. 01/04	Wind 90 MPH Prob	Karst KP	Land slide KP	Tornado Prob	Wild-fire KP
WILLIAMSBURG	12537	3468	1	28	0.034	0.000	1.000	0.000E+00	2.435
WINCHESTER	22576	9084	3	15	0.020	2.999	1.000	0.000E+00	2.047
WISE COUNTY	40125	14513	3	399	0.020	1.000	2.814	0.000E+00	2.704
WYTHE COUNTY	26639	9852	2	39	0.020	2.378	1.173	0.000E+00	2.033
YORK COUNTY	59416	14474	1	1947	0.065	0.000	1.307	1.948E-04	2.406

Flood Analysis

Analysis techniques for flood hazards made use of flood policy information for the jurisdiction analysis and available floodplain mapping for the state facility analysis. The flood policy technique first scaled the number of flood insurance policies in a county or city by the number of households from the 2000 Census. Then a population weighted score was developed and ranked to represent the relative flood impacts at a jurisdictional level. For state facilities, when flood mapping was available, each facility was assigned a probability of being in a floodplain based on the intersection of the facility location and the floodplain mapping.

Wind (Hurricane) Analysis

The wind design map from ASCE 7-98 (Figure 3-6) was used within a GIS to determine each county's and city's maximum 50-yr wind speed. For a majority of Virginia, this relates to 90 mph. Based on calculations within ASCE 7-98, 90 mph was used as a standard for determining wind hazard probability. In Table 3-9, jurisdictions closer to the cost will have a higher probability than 2% (50-yr) for the 90 mph wind speed.

Karst

Figure 3-13 shows how the USGS karst mapping (Figure 3-8) was converted to use with the KP technique. For jurisdictions with some karst area, a hazard from 3 (high) to 2 (medium) was calculated based on an area weighted average. Jurisdictions neighboring these counties were assign 1 (low) and all others were assigned 0 (none).

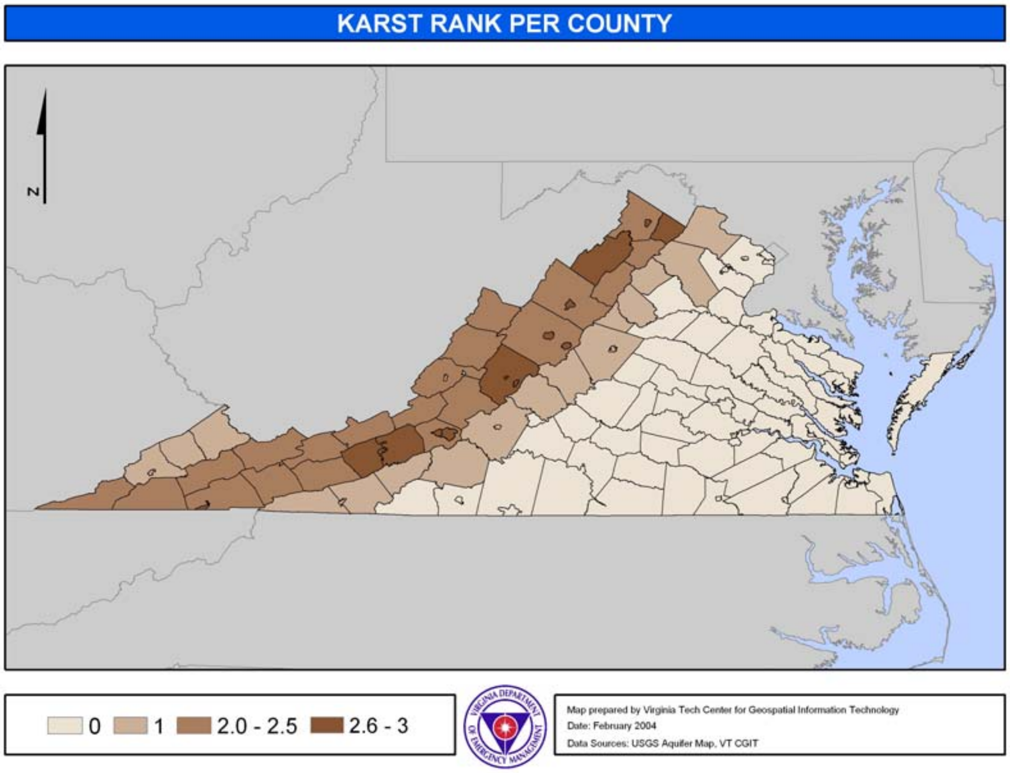


Figure 3-13. Karst Relative Severity Based on USGS Aquifer Mapping.

<u>Landslide</u>

Landslide Analysis also made use of the KP technique, as shown in Figure 3-14. Landslide hazards were ranked 1-3 based on the landslide susceptibility and incidence class from the USGS landslide mapping. Low susceptibility and moderate susceptibility & low incidence were assigned ranks of one. Moderate susceptibility and high susceptibility & low incidence were assigned ranks of two. High susceptibility and high susceptibility & high incidence were assigned ranks of three.

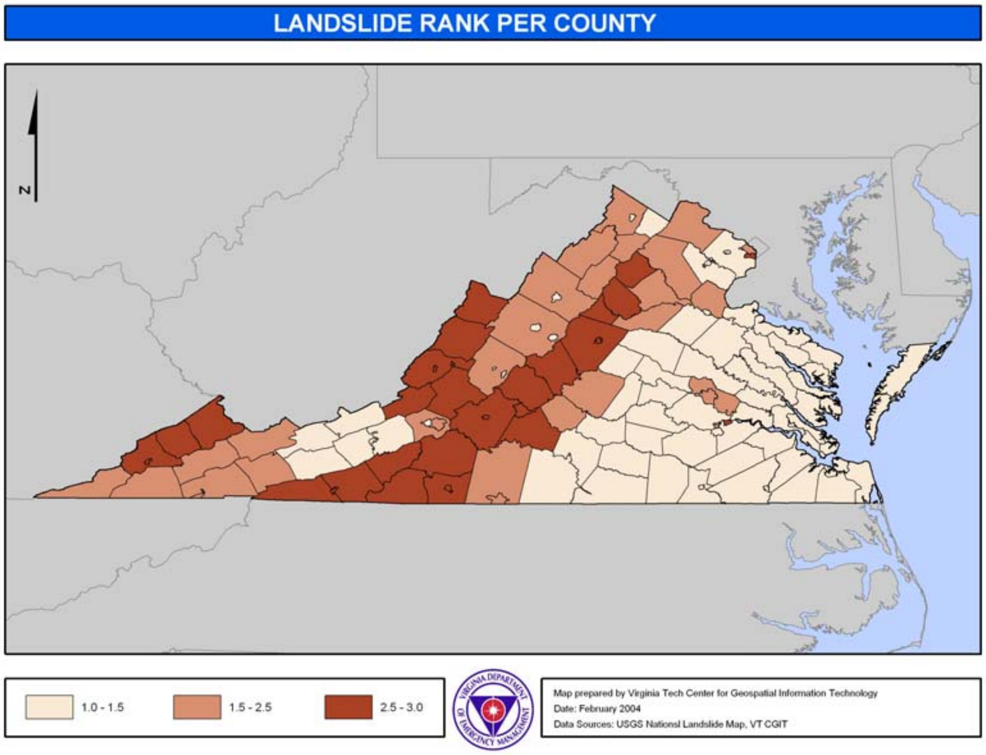


Figure 3-14. Landslide Relative Severity Based in USGS Landslide Mapping.

Tornado

Tornado Analysis made use of historical tornado statistics (counts, path length and width) to determine annual probably for each jurisdiction. Most of the source data came from NOAA Storm Prediction Center at http://www.spc.noaa.gov/archive/tornadoes/ and the method used was based on FEMA 361 Design and Construction of Community Shelters.

Wildfire

Wildfire Analysis made use of the Virginia DOF fire hazard mapping, as shown in Figure 3-11, to utilize the KP technique. The three hazards levels of high (3), medium (2), and low(1) were uses unchanged.

Jurisdiction Vulnerability Analysis

The Jurisdiction Vulnerability Analysis made use of the jurisdiction hazard vulnerabilities to assess the impact of hazards on the population of Virginia. Table 3-9 showed for the seven hazard analysis types (winter, flood, wind, karst, landslide, tornado, and wildfire) either the probability or relative risk for each hazards. For the Jurisdiction Vulnerability Analysis, each of these hazard levels were weighted by the population of the jurisdiction and then ranked. For flooding, the number of policies was first weighted by the number of households before weighting by population. The jurisdictions with the higher hazards were given the higher rank. The final overall ranking was then develop by adding all of the individual ranks with a weighting given based on the high, medium, or low statewide relative risk (shown in Table 3-2). Figure 3-15 and Table 3-11 shows the results of this analysis.

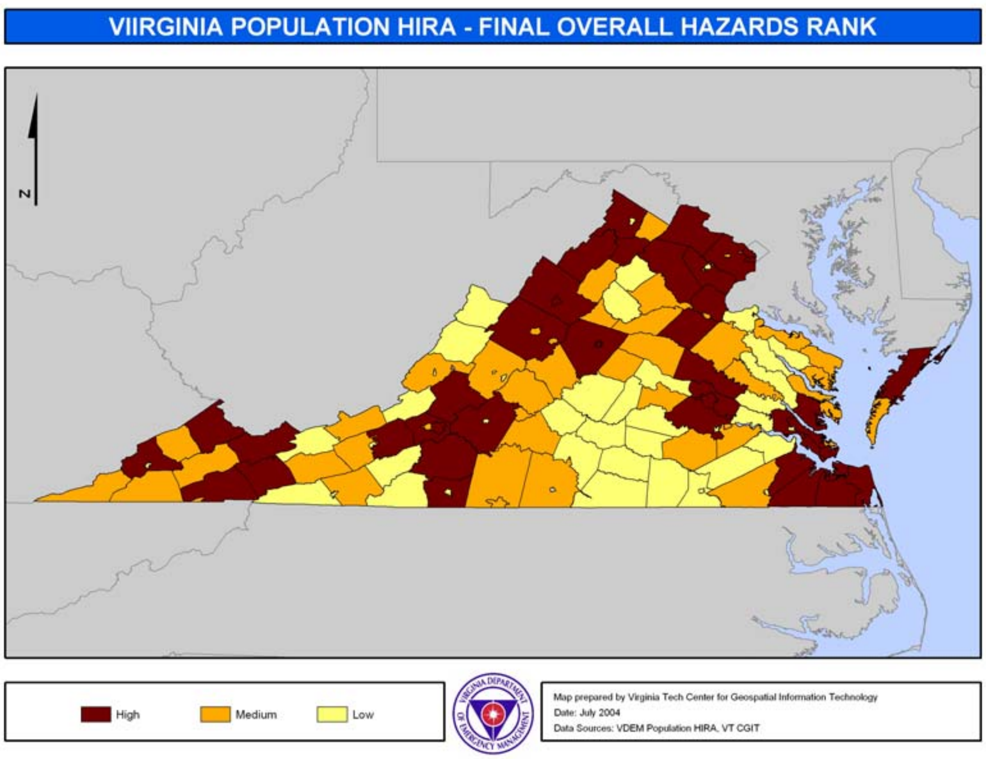


Figure 3-15. Jurisdiction Vulnerability Analysis Hazard Rankings

The top ten jurisdictions for overall hazard vulnerability (based on population weighting) were the following:

1. Virginia Beach
2. Norfolk
3. Fairfax County
4. Roanoke City
5. Newport News
6. Loudoun County
7. Alexandria
8. Henrico County
9. Roanoke County
10. Portsmouth

Table 3-11. Jurisdiction Vulnerability Analysis Hazard Rankings (Higher values more severe).

COMMUNITY_	Winter Rank	Flood Rank	Wind Rank	Karst Rank	Land Rank	Tornado Rank	Wildfire Rank	Final Rank
ACCOMACK COUNTY	52	129	127	39.5	61	61	81	99
ALBEMARLE COUNTY	112	87	108	122	125	69	122	113
ALEXANDRIA	**127**	**123**	**118**	**39.5**	**129**	**111**	**107**	**128**
ALLEGHANY COUNTY	59	130	22	96	22	19.5	35	53
AMELIA COUNTY	8	10	19	39.5	16	110	26	19
AMHERST COUNTY	84	43	77	99	100	19.5	90	63
APPOMATTOX COUNTY	44	7	31	39.5	62	39	42	16
ARLINGTON COUNTY	132	86	120	39.5	127	19.5	119	100
AUGUSTA COUNTY	118	98	104	129	108	93	109	118
BATH COUNTY	26	33	3	86	30	19.5	5	7
BEDFORD	23	4	10	83	45	19.5	16	3
BEDFORD COUNTY	106	65	103	113	120	74	111	103
BLAND COUNTY	38	57	9	90	3	19.5	13	15
BOTETOURT COUNTY	97	97	74	121	98	19.5	85	91
BRISTOL	54	49	42	106	67	134	60	78
BRUNSWICK COUNTY	35	15	49	39.5	38	116	55	44
BUCHANAN COUNTY	80	105	71	98	96	50	95	94
BUCKINGHAM COUNTY	47	8	35	39.5	66	62	45	27
BUENA VISTA	18	60	6	94	11	19.5	11	9
CAMPBELL COUNTY	102	35	98	39.5	111	63	108	85
CAROLINE COUNTY	67	36	57	39.5	56	71	71	49
CARROLL COUNTY	79	20	70	97	95	55	88	62
CHARLES CITY COUNTY	3	14	11	39.5	9	41	20	2
CHARLOTTE COUNTY	16	5	25	39.5	23	119	32	25
CHARLOTTESVILLE	94	37	89	101	106	129	69	101
CHESAPEAKE	121	133	133	39.5	122	77	125	120
CHESTERFIELD COUNTY	125	108	125	39.5	126	107	133	123
CLARKE COUNTY	64	54	27	100	35	82	30	54
COLONIAL HEIGHTS	31	64	39	39.5	57	19.5	33	24
COVINGTON	21	78	8	82	43	19.5	9	20
CRAIG COUNTY	27	58	4	85	27	19.5	6	12
CULPEPER COUNTY	103	40	84	39.5	93	81	83	87
CUMBERLAND COUNTY	29	41	14	39.5	6	59	15	18
DANVILLE	75	56	97	39.5	101	19.5	97	65
DICKENSON COUNTY	74	70	44	93	86	53	68	69
DINWIDDIE COUNTY	41	23	67	39.5	55	103	70	50
EMPORIA	1	47	5	39.5	1	133	3	32
ESSEX COUNTY	34	83	16	39.5	14	19.5	21	21
FAIRFAX	85	96	55	39.5	46	19.5	25	60
FAIRFAX COUNTY	**134**	**125**	**131**	**39.5**	**134**	**121**	**134**	**132**
FALLS CHURCH	50	51	17	39.5	15	120	4	47
FAUQUIER COUNTY	113	82	100	112	109	79	100	110
FLOYD COUNTY	43	9	29	88	72	42	37	22
FLUVANNA COUNTY	66	50	54	39.5	58	126	66	75
FRANKLIN	5	89	23	39.5	7	108	14	43

COMMUNITY_	Winter Rank	Flood Rank	Wind Rank	Karst Rank	Land Rank	Tornado Rank	Wildfire Rank	Final Rank
FRANKLIN COUNTY	98	80	93	105	113	19.5	104	92
FREDERICK COUNTY	114	71	102	128	110	72	112	108
FREDERICKSBURG	60	90	48	39.5	44	118	50	83
GALAX	37	1	7	81	40	19.5	23	6
GILES COUNTY	72	74	41	102	52	19.5	54	48
GLOUCESTER COUNTY	57	121	117	39.5	73	96	96	104
GOOCHLAND COUNTY	56	26	46	39.5	37	68	61	34
GRAYSON COUNTY	73	24	43	92	85	19.5	58	33
GREENE COUNTY	68	34	36	91	82	101	57	68
GREENSVILLE COUNTY	9	6	20	39.5	17	98	22	13
HALIFAX COUNTY	48	48	75	39.5	75	58	82	52
HAMPTON	109	132	129	39.5	118	100	117	124
HANOVER COUNTY	115	68	111	39.5	99	115	118	112
HARRISONBURG	104	81	86	126	79	19.5	78	90
HENRICO COUNTY	**130**	**111**	**124**	**39.5**	**132**	**109**	**130**	**127**
HENRY COUNTY	78	67	99	39.5	116	97	114	96
HIGHLAND COUNTY	4	19	1	80	4	19.5	1	1
HOPEWELL	39	30	59	39.5	90	132	49	70
ISLE OF WIGHT COUNTY	49	99	110	39.5	64	99	77	95
JAMES CITY COUNTY	71	118	115	39.5	84	88	99	105
KING AND QUEEN COUNTY	20	28	18	39.5	2	78	12	17
KING GEORGE COUNTY	58	29	47	39.5	47	73	59	39
KING WILLIAM COUNTY	42	75	28	39.5	29	114	34	58
LANCASTER COUNTY	10	107	82	39.5	34	106	38	76
LEE COUNTY	92	76	63	110	83	47	79	82
LEXINGTON	25	11	12	95	5	19.5	2	4
LOUDOUN COUNTY	**131**	**116**	**119**	**131**	**130**	**89**	**129**	**129**
LOUISA COUNTY	76	25	66	39.5	54	90	75	61
LUNENBURG COUNTY	11	3	21	39.5	18	85	29	10
LYNCHBURG	108	69	106	39.5	121	19.5	113	88
MADISON COUNTY	61	38	26	87	70	57	40	37
MANASSAS	30	63	15	39.5	8	19.5	8	11
MANASSAS PARK	89	12	85	39.5	65	19.5	52	42
MARTINSVILLE	24	17	34	39.5	80	19.5	46	8
MATHEWS COUNTY	6	122	91	39.5	12	113	24	86
MECKLENBURG COUNTY	51	31	79	39.5	59	43	86	41
MIDDLESEX COUNTY	7	102	80	39.5	25	86	27	67
MONTGOMERY COUNTY	123	94	107	133	105	46	120	111
NELSON COUNTY	45	72	33	89	76	40	53	45
NEW KENT COUNTY	22	46	45	39.5	32	94	48	35
NEWPORT NEWS	**116**	**124**	**130**	**39.5**	**123**	**128**	**128**	**130**
NORFOLK	**122**	**131**	**132**	**39.5**	**124**	**131**	**127**	**133**
NORTHAMPTON COUNTY	19	112	116	39.5	26	56	28	74
NORTHUMBERLAND COUNTY	13	110	90	39.5	20	80	36	72
NORTON	14	32	2	79	21	19.5	7	5
NOTTOWAY COUNTY	28	2	37	39.5	31	105	51	30

COMMUNITY_	**Winter Rank**	**Flood Rank**	**Wind Rank**	**Karst Rank**	**Land Rank**	**Tornado Rank**	**Wildfire Rank**	**Final Rank**
ORANGE COUNTY	96	27	68	39.5	74	64	72	64
PAGE COUNTY	91	95	61	109	69	51	74	89
PATRICK COUNTY	36	16	50	39.5	89	49	65	28
PETERSBURG	55	62	83	39.5	77	130	84	93
PITTSYLVANIA COUNTY	81	21	101	39.5	112	87	106	80
POQUOSON	12	128	95	39.5	19	19.5	18	57
PORTSMOUTH	**100**	**126**	**128**	**39.5**	**103**	**123**	**98**	**125**
POWHATAN COUNTY	69	18	62	39.5	50	67	76	46
PRINCE EDWARD COUNTY	62	52	51	39.5	42	44	63	40
PRINCE GEORGE COUNTY	46	55	73	39.5	68	122	89	77
PRINCE WILLIAM COUNTY	133	120	126	39.5	128	83	131	122
PULASKI COUNTY	90	79	87	124	71	19.5	92	81
RADFORD	70	22	38	103	33	19.5	43	29
RAPPAHANNOCK COUNTY	40	44	13	84	49	45	19	26
RICHMOND	128	85	121	39.5	131	127	124	121
RICHMOND COUNTY	32	53	30	39.5	13	66	17	31
ROANOKE	**126**	**115**	**113**	**134**	**119**	**125**	**110**	**131**
ROANOKE COUNTY	**124**	**106**	**109**	**132**	**117**	**102**	**121**	**126**
ROCKBRIDGE COUNTY	65	101	53	108	63	19.5	62	66
ROCKINGHAM COUNTY	119	117	105	130	114	52	115	115
RUSSELL COUNTY	82	66	72	115	81	54	87	79
SALEM	93	114	64	120	51	19.5	56	84
SCOTT COUNTY	87	59	58	107	78	48	80	73
SHENANDOAH COUNTY	105	100	88	123	97	70	93	106
SMYTH COUNTY	101	91	81	119	88	75	91	102
SOUTHAMPTON COUNTY	33	84	76	39.5	36	65	39	59
SPOTSYLVANIA COUNTY	117	92	112	39.5	102	112	123	116
STAFFORD COUNTY	120	113	114	39.5	115	84	126	117
STAUNTON	95	73	65	118	53	19.5	64	71
SUFFOLK	86	119	123	39.5	91	92	101	114
SURRY COUNTY	2	45	24	39.5	10	91	10	23
SUSSEX COUNTY	15	61	32	39.5	28	104	31	36
TAZEWELL COUNTY	110	104	94	125	92	19.5	103	98
VIRGINIA BEACH	**129**	**134**	**134**	**39.5**	**133**	**124**	**132**	**134**
WARREN COUNTY	99	103	78	117	87	95	94	109
WASHINGTON COUNTY	111	77	96	127	104	76	105	107
WAYNESBORO	63	88	52	111	41	19.5	44	56
WESTMORELAND COUNTY	53	93	40	39.5	39	60	47	55
WILLIAMSBURG	17	39	56	39.5	24	19.5	41	14
WINCHESTER	88	13	60	116	48	19.5	67	38
WISE COUNTY	107	109	92	104	107	19.5	102	97
WYTHE COUNTY	77	42	69	114	60	19.5	73	51
YORK COUNTY	83	127	122	39.5	94	117	116	119

State Facility Vulnerability Analysis

Besides looking at vulnerability to jurisdictions, the HIRA also looked at vulnerability to state facilities. The HIRA was not able to include local assessment information, because no local plans were available when the HIRA was being complete.

Facility Database and Locations

This Plan only looked at state owned, leased, or managed facilities. The most comprehensive source of this information was the Virginia Agency Property System (VAPS) database, maintained by the Division of Risk Management in the Virginia Department of the Treasury. VAPS contains information for almost 13,000 locations for around 230 state agencies in Virginia. The term “locations” was used instead of “structures”, because VDEM decided that all analyses needed to be summarized by locations of state agencies. Certain structures, especially in Richmond, VA (the state capitol), have multiple state agency locations in the same structure.

VAPS only contains structure information. The database does contain a field labeled “critical type”, which contains a code that describes the type of facility at that location. Table 3-12 lists the descriptions of the different types of facilities accounted for in the database. **The critical facilities were taken into account when using the KP methodology, where critical facility locations received a higher score in assessing their vulnerability as compared to other state owned or operated facilitie**s. Following the completion of the HIRA, state agencies were given building-specific and hazard-specific information for their agencies. These were provided to the agencies at the 2nd meeting and through a password-protected website. Due to security issues with the release of this information, maps of the locations of the various type of critical facilities and counts of the various types of facilities can not be included in this section.

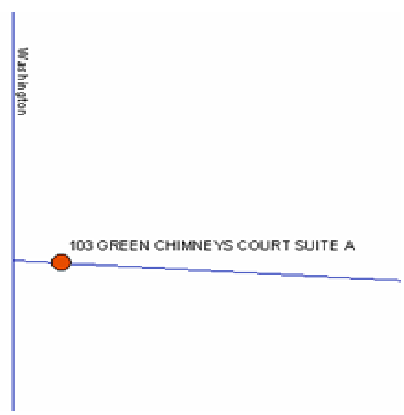
Table 3-12. Critical Building Types within the VAPS Database.

Code	Facility Type	Description
CE	Essential	Facilities are essential to health and welfare of the whole population and are especially important following hazard events. These include hospitals and other medical facilities, police and fire stations, emergency operations centers, and evacuation shelters.
CT	Transportation Systems	Including Airways (airports, heliports); Highways (bridges, tunnels, roadbeds, overpasses, transfer centers); Railways (trackage, tunnels, bridges, rail yards, depots); and Waterways (canals, locks, seaports, ferries, harbors, dry-docks, piers).
CL	Lifeline Utility Systems	Including potable water supplies and treatment facilities; wastewater lines and treatment facilities; oil and natural gas lines and supplies; electric power lines and generators; and communications systems.
CP	High Potential Loss	Facilities are facilities that would have a high loss associated with them, such as nuclear power plants, dams, and military installations.
CH	Hazardous Materials	Facilities, including facilities housing industrial/hazardous materials, such as corrosives, explosives, flammable materials, radioactive materials, and toxins.
CV	Vulnerable	Facilities, including the following: a. schools (all age groups); b. facilities that house special populations, such as nursing homes, prisons, etc.; c. major employers and/or financial intuitions/centers; d. high density residential or commercial centers that, if damaged, may result in high death tolls and injury rates.
CA	Archival	Include facilities that: a. house irreplaceable artifacts, records, equipment, or research (e.g., museums); b. have some special or unique cultural/historic value (i.e., historic landmarks or districts); c. represent some special or unique natural resource value, including public recreation areas, parks, forests, important natural habitats, etc.; d. are areas protected under state or federal law.
CI	Important	Facilities that help to ensure a full recovery of the jurisdiction following a hazard event. These would include some government functions and certain commercial establishments such as grocery stores, hardware stores, and gas stations.

The VAPS database did not address critical infrastructure. The Virginia Department of Transportation (VDOT) is currently in the process of developing a road infrastructure database and the Virginia Information Technology Agency (VITA) is compiling information on other critical infrastructure. These will be added to the Mitigation Database being developed for the updated plan for 2007. Unfortunately, neither database was available during the HIRA.

Proposed projects address the need for a more complete state facility database which addresses the need for a standardized database for identifying and tracking community assets including critical and non-critical facilities. Project 3.5.2 Comprehensive State Facility Inventory Database would consolidate and enhance the existing data into one database.

In the attempt to locate these facilities spatially, several methods were utilized. The two main locating methods that were implemented were geocoded facilities and polygons outlining facilities. Geocoding or "address matching" uses nonspatial information of locations (i.e. VAPS database) and converts the location information into a spatial address (i.e. the geocoded point). In geocoding, information from the VAPS database was compared against the information in the StreetMap USA database. When the two databases had matching information a point location was assigned to the entry in the VAPS database. Figure 3-16 below shows an example of geocoding.



Geocoding Example:
Probation & Parole District # 41
103 Green Chimneys Court Suite A
Ashland, VA 23005

Figure 3-16. Geocoding Example

The lack of or presence of inaccurate information in the databases resulted in some facilities not being identified with a point location. Only about 1/3 of the locations in the VAPS database produced geocoded points. Many of the VAPS address fields were incomplete or not in an E911 style format. Also, many of the higher value structures in the state (the Governor's Mansion, State Capitol Building, major university buildings) did not have detailed state addresses or only contained the administrative address of the agency. Figure 3-17 shows the locations of geocoded facilities within Virginia.

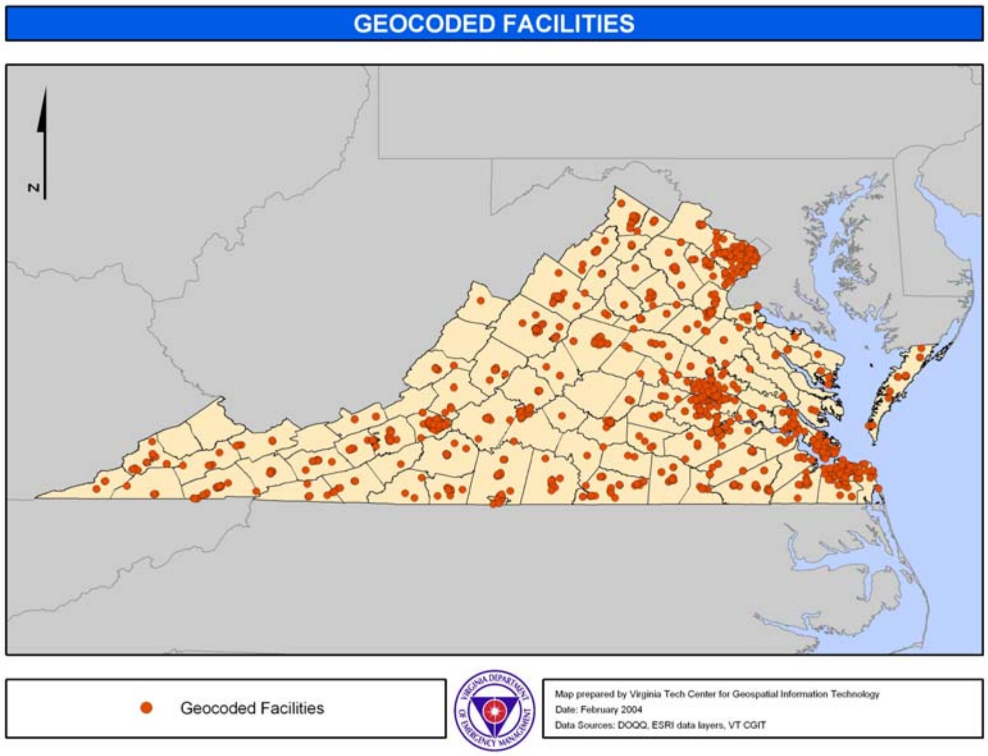


Figure 3-17. Geocoded State Facility Locations in Virginia.

When geocoding did not work, an alternative approach was needed. Therefore, an alternative approach for detailing polygons was used for the higher value locations. First, the VAPS database was sorted by property and contents values. Those locations that could be considered “institutions”, such as hospitals, correctional facilities, state parks, community colleges and state colleges/universities, were lumped together and spatially located to an appropriate location using various methods (such as ESRI data and online map search engines). After the institution was located, USGS DOQQ imagery was added to the GIS editing tools were used to draw a “polygon” around the perimeter of the facilities. The resulting facility polygon was then used in analyses to represent all the appropriate locations listed in the VAPS database. Figure 3-18 shows an example of the polygon method and Figure 3-19 shows statewide polygons.

Polygon Example:
James River Corrections Center
DOQQ: Perkinsville SW 37077f78

Figure 3-18. Polygon Location Example.

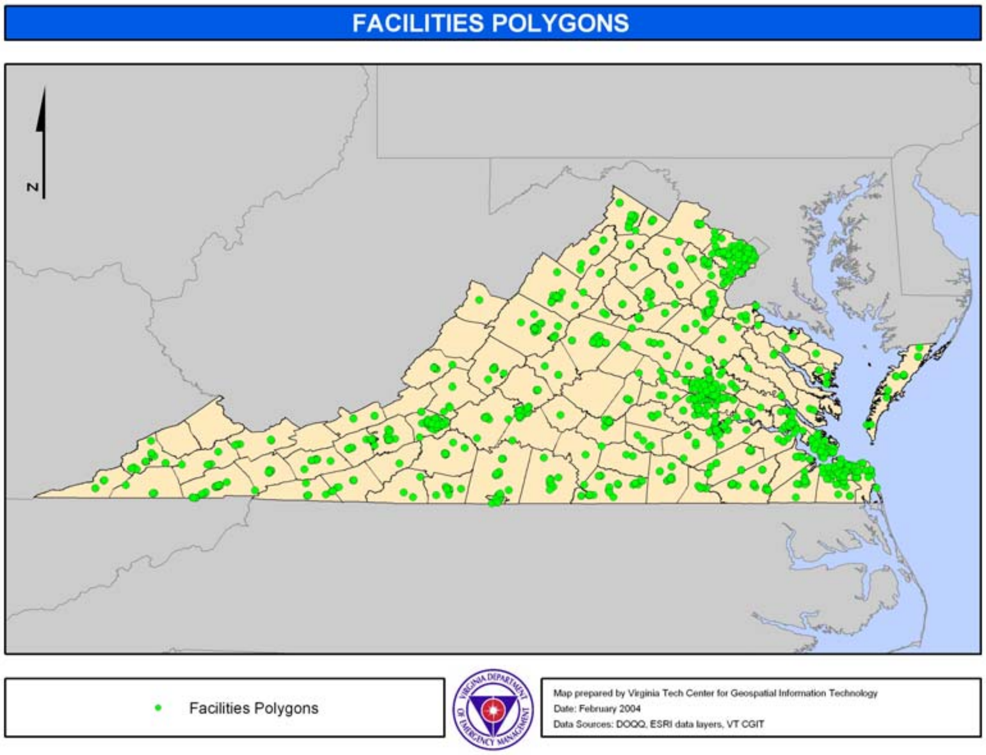


Figure 3-19. Polygon State Facility Locations in Virginia.

If a VAPS database entry could not be located by the polygon or geocode method, then the "county" method was used to at least assign a county or independent city to the location. Table 3-13 summarizes the number and dollar value of location using the geocode, polygon, or county methods.

Table 3-13. Virginia Agency Property System (VAPS) Database Location Summary

Location Method	Number of Locations	Percent of Total Value in Virginia
Geocode	2,406	22%
Polygon	5,081	73%
County	5,431	5%
Totals	12,918	100%

Facility Analysis

To conduct the state facility HIRA, the scale of the hazard mapping and the facility location had to be compared. Table 3-14 shows the analysis level used for each hazard and the technique used.

Table 3-14. Analysis Methods Used for the Facility Analysis

Hazard Analysis	Analysis Level	Technique
Winter Storm	County	KP w/critical adjustment
Flooding	Geocode	Probability (Yes, no, partial, unknown)
Wind	County	Probability
Karst	County	KP w/critical adjustment
Landslide	County	KP w/critical adjustment
Tornado	County	Probability
Wildfire	Geocode	KP w/critical and fire building adjustment

For hazards with detailed location information (flood and wildfire), the limiting factor was the location mapping. For flooding with geocoded locations, locations were “yes”, “no”, or “unknown” for being in a floodplain. For polygon locations, flooding was calculated as the portion of the polygon area that intersected with a floodplain boundary polygon. The percent of the polygon in the floodplain was used, along with the damage level assumption, to provide a weighted damage approach for all actual locations assigned to a polygon. For example, if 10% of a polygon was in a floodplain and the polygon represented 40 structures, then it was assumed that 4 structures were in the floodplain. For all polygon location, floodplain boundaries were taking from existing digital floodplain data or digitized to allow for analysis. Figure 3-20 show the jurisdictions where floodplain mapping was available, completed digitized, partially digitized, or none. For county locations, the VAPS database already indicated “yes”, “no”, or “unknown” for being in a floodplain, so these used, since no other site specific information was available.

Fire hazards presented a different challenge. For geocoded locations, relative risk levels (low=1, medium=2, high=3) were assigned. For polygons and counties, an area-weighted average was calculated and assigned to the location.

For all other hazards, the limiting factor was the hazard mapping precision at only the county or jurisdiction level. For these hazards, each location was assigned the probability or relative risk value from Table 3-10 based on the pertinent jurisdiction. Therefore, the only “unknown” hazards for all of these locations was for flooding where the mapping was not in the vicinity of a geocoded location, or for county locations where the VAPS database did not have a value. For all other hazards, every location was assigned either a hazard probability or relative risk. Table 3-14 shows the technique used for each hazard. Proposed projects would increase the data availability for analysis in future revisions of this plan. Some of the proposed data projects from Information and Data Development objectives one (Identify data needs and sources) and two (Identify data analysis methods) include: 3.1.1 Climate and Natural Hazard Information Collection; 3.1.2 Establish and Maintain the Virginia Hazard Mitigation Database; 3.3.1 State Hazard Mitigation Website Maintenance. These data deficiencies are addressed in Appendix H.

The KP technique used for relative risk for these other hazards took into account the relative probability of hazard occurrence (low=1, medium=2, high=3) and the possible relative impact of that hazard on a structure, contents, and continuity of business operations. When supplemental information was available, it was used to differentiate between locations. For example, the VAPS database included fire construction rating for all locations and noted if a location was a critical facility. For the fire relative risk calculation, a better fire rating for a location lowered the overall relative risk. For all relative risk calculations, a critical facility was given a higher relative risk for continuity of business operations.

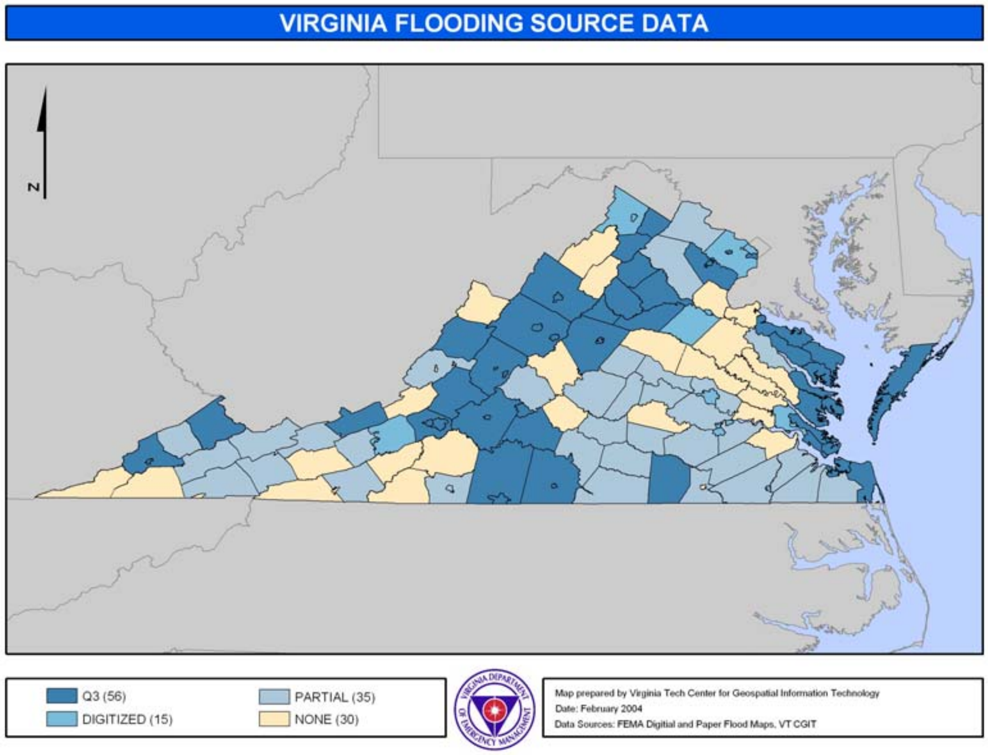


Figure 3-20. Digital Floodplain Data Used for Facility Analysis.

<u>Facility Summaries</u>

The final step in the state facility analysis was summarizing these results for each of the approximately 230 state agencies. Appendix F contains the overall state facility summary and the individual summary for each agency. Since each hazard had a unique combination of analysis level and risk method, there was a need to provide some sort of common basis to compare between hazard and between agencies. Therefore, each state agency was ranked versus all other agencies using the average probability or relative risk for all locations of that agency. These rank percentiles were then presented with the actual probability or relative risk values in the HIRA report. This allowed each agency to see how they fared internally (what was the highest hazard risk) and externally (what hazards were above the 50th, 75th, etc. statewide). By providing this common basis, the HIRA gave each agency valuable information that was then used to develop mitigation strategies and projects. Table 3-15 provides the average value for each hazard for all state facility locations.

Table 3-15. State Facility Analysis Methods Summary

Hazard Analysis	Analysis Level	Average Facility Value
Winter Storm	Relative Risk	0.33
Flooding	Probability (% locations)	25%
Wind	Probability (exceeding 90 mph)	3.30%
Karst	Relative Risk	0.13
Landslide	Relative Risk	0.33
Tornado	Probability	0.02%
Wildfire	Relative Risk	0.40

3.4 Estimating Potential Losses

This Plan had inadequate information to develop potential loss estimates for most hazards. The two primary limitations were no completed local plans, which limited jurisdiction loss estimates, and incomplete state facility information. As mentioned earlier, the next update to this plan in 2007 will include information from local risk assessments and new statewide information, which will be included in the new Mitigation Database (Project 3.1.2 Establish and Maintain the Virginia Mitigation Database in Appendix H). Table 3-16 summarizes what information will be needed to perform these calculations in future plans.

Table 3-16. Loss Estimate Data Needs

Hazard Analysis	Loss Estimation Limitation	Data Needs
Winter Storm	Defined hazard and damage criteria	Jurisdiction: Local Plans State Facility: Structure Design Information
Flooding	Incomplete Information	Jurisdiction: Local Plans State Facility: Elevation, Flood Profiles
Wind	Defined damage criteria	Jurisdiction: Local Plans State Facility: Structure Design Information
Karst	Defined damage criteria	Jurisdiction: Local Plans State Facility: Structure Site Information
Landslide	Defined damage criteria	Jurisdiction: Local Plans State Facility: Structure Site Information
Tornado	Defined damage criteria	Jurisdiction: Local Plans State Facility: Structure Design Information
Wildfire	Defined damage criteria	Jurisdiction: Local Plans State Facility: Structure Site Information

Many of the hazards do not have defined damage estimate criteria. The HAZUS-MH model currently only addresses flood and earthquakes, with a preliminary hurricane wind model. If the hurricane wind model is fully developed within the next few years, it could be used for future plan. All other hazards besides flooding and hurricane wind require some standard, established method for estimating losses. For many hazards that are very site specific, like karst, fire, and landslide, some sort of site and building assessment method will be needed to estimate the true risk from those hazards. Tornado hazards can be defined with a probability, but for Virginia these probabilities are so low that standard wind design standards address that need. Winter storms need both the hazard and the damage better defined. Virginia often gets winter weather with a mixture of snow, ice, sleet, and freezing rain. A method of estimating losses for each of these types of storms is currently not known.

<u>Flood Loss Estimation for State Facilities</u>

Even with incomplete information, a loss estimate was developed for flood losses to state facilities. If the state owned the facility, then dollar losses were estimated based on the structure and contents values. If the state leased the location, only contents losses were estimated. The VAPS database had insufficient information (no employee number or annual budget) to estimate loss of function or displacement costs.

Since building elevation and flood profile information was not known for the 3230 locations in the floodplain (25% of all state locations), the lookup table shown in Table 3-17 was used to approximate flood depth. Historical, high-value buildings were assumed be at or above the 100-yr elevation. Structures built pre-FIRM that were not historical were assume to have more damage than post-FIRM structures. Lower valued structures were also assumed to have more damage than higher value ones.

Table 3-17. 100-yr Flood Depth Estimation based on Available VAPS Database

Value	Built before 1950	Built between 1950 and 1973 (Pre-FIRM)	Built after 1973 (Post-FIRM)
> $500,000	0 feet	2 feet	1 foot
< $500,000	1 foot	3 feet	2 feet

Values in Table 3-17 were then assigned default depth-damage relationships from FEMA's Benefit-Cost Riverine Full Data Module software for 1 or 2 story without basement structures. It was assumed that damage begins with a 25-yr flood with $0 damage for structure and contents. The amount of damage at 100-yr flood is maximum dollar amount of damage for all flood frequencies, as shown in Figure 3-21.

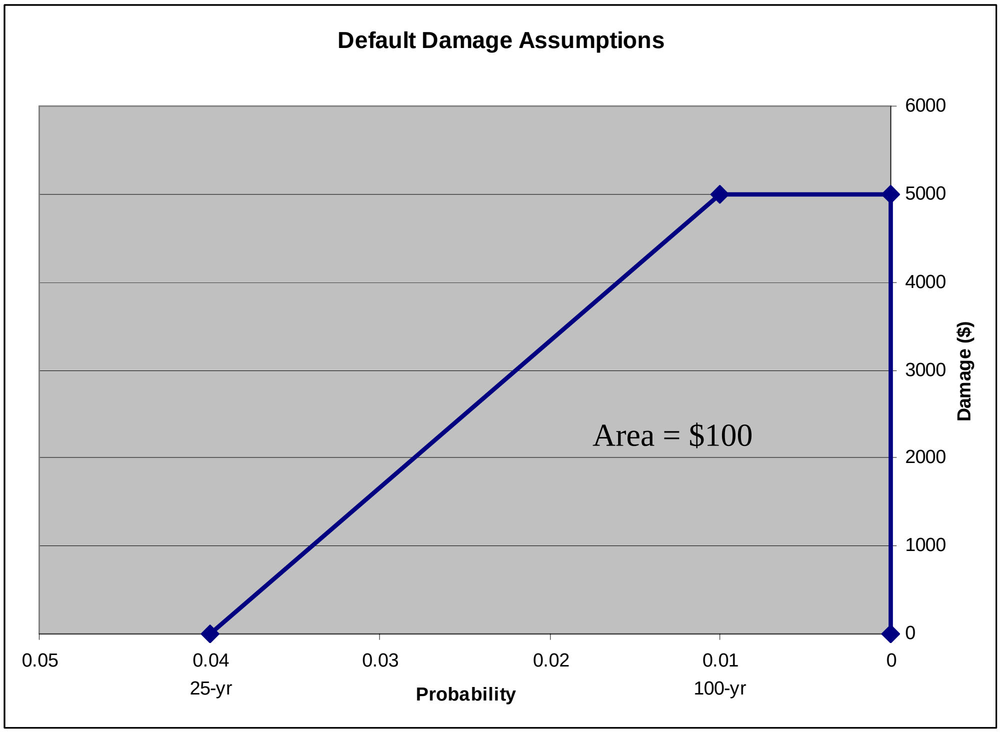


Figure 3-21. Default Flood Damage Assumption used for Flood Loss Estimation.

When the VAPS database contained information in the fields needed to calculate this loss estimate, a dollar loss was calculated for each structure. These were summarized for each agency, with an indication of how many of the flood structures had sufficient data for the estimate. For example, the HIRA analysis may have found 10 locations were shown to be in the floodplain, but the VAPS database may have only had information for 7 of the structures to estimate the annual loss. When an agency had a polygon with only a partial area in the floodplain, the number of structures used to develop the loss estimate could exceed the number of estimated flooded locations, since analysis uses the partial floodplain area to weight the flood impact. Appendix F contains in the agency facility HIRA summaries the loss estimation for each agency, including the number of structures that have sufficient information.

The total annual flood loss potential to state facilities and their contents was estimated to be at least $1,894,882.